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# Technology Review

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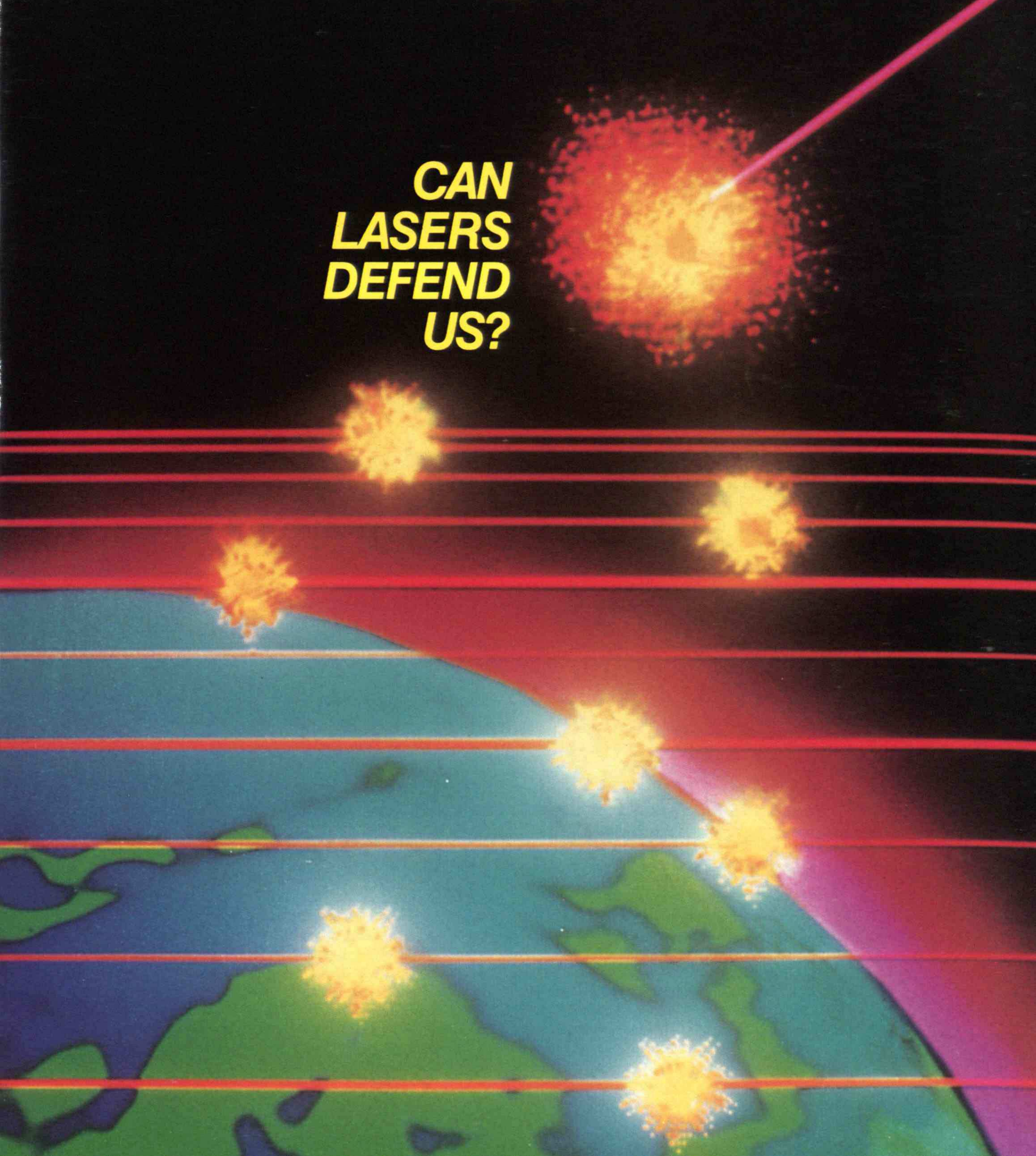


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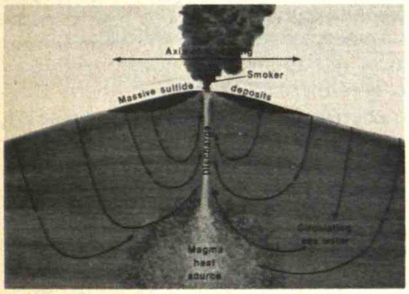

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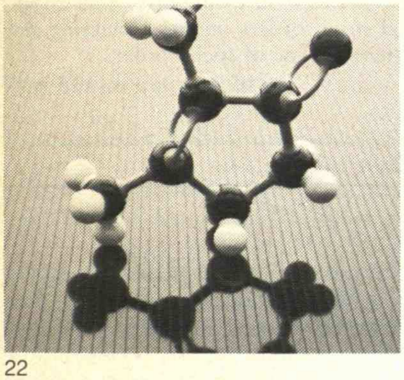
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## FIRST LINE

### Battling Irrationality

*Those of us who daily engage in writing and editing about science and technology too easily put our work into the context of pages and deadlines, failing to see aspects of the forest because of the trees. So when Victor K. McElheny director of M.I.T.'s Vannevar Bush Fellowships, shared with us his eloquent words about some larger issues in science writing prepared for a conference in Stuttgart early this year, we asked to adapt a few of his observations into a guest editorial.*

There is an inherent resistance among scientists to popularization—the discussion of complex issues in terms that laymen can understand. Any interruption in research to make explanations to naive people represents a risk to the person who does the research. Explanation is seductive. It is a break in concentration. Obsessive concentration is essential to solving many problems in research.

Explanation also involves simplification of complex facts and ideas. The most risky simplification of all involves the shift from the doubt and uncertainty that constantly accompany the researcher's work to the temporary certitudes of explanations. For the naive observer, any subject, despite many indefinite aspects, is frozen, codified into definite assertions. Hypotheses may be transformed prematurely into facts.

Much of the tension felt by science reporters derives from the often-successful effort of overcoming this deep resentment among scientists.

Because I recognize, and respect, scientists' hesitation at being interrupted, I am especially grateful for the astonishing generosity with information that I have encountered with virtually every scientist I have contacted. Clearly one reason for this is their determination to carry on the age-old battle against irrationality, particularly the irrational factors that may prevent people from making use of the findings of science through technology.

No matter how uncomfortable is the process of explanation, there is no substitute for the scientist or the engineer or the doctor as an authoritative source of information to be transmitted to the public by journalists. That this process proceeds as well as it does must result from the conviction in both scientist and journalist that to increase people's knowledge about science, and about the applications of science, is to increase the human liberty that is so cherished by our age. Knowledge of the factors shaping the circumstances of people's lives gives people increased control over those circumstances.

For me, the ideals of the Enlightenment are alive. I believe in the idea of progress. For me, new scientific knowledge, coming in an ever-widening stream from the Indies of the intellect, far from buttressing established social orders, makes inevitable the constant change of social order.

## LETTERS

### Dogging a Watchdog Commission

As a "concerned scientist," I take strong exception to Robert Cowen's view of the "Challenge for Genetic Engineering," (*October, page 8*). While I agree that the ethical issues of such research have not been neglected completely—the National Institutes of Health, Congress, and the President have gone through the motions of attempting to regulate gene-splicing—they have certainly not been resolved.

"The splitting of the atom," said Einstein, "changed everything save our modes of thinking, and thus we drift towards unparalleled catastrophe." The splitting of the gene likewise changes everything again, and yet the old ways of thinking remain. The full ramifications of the first experiments in genetic engineering (and the thousands more to come) cannot possibly be foreseen, yet enormous expectations have propelled the NIH into "biotech" with the same blind faith that sent the Atomic Energy Commission in quest of the peaceful atom.

Genetic engineering involves much more than mutating bacteria, curing diseases, and improving crop yields. It forever alters the genetic pool of the universe according to human priorities. Corporations stand to profit enormously from such decisions. I refuse to grant a committee of 19 people at the NIH, or a "bioethics

watchdog commission" still to be created by Congress, the right to make such judgments for 4 billion of their brethren.
Albert Donnay
Baltimore, Md.


### Affront to the President

The cover illustration for the January issue, depicting the president of the United States as a rootin', tootin' cowboy, is in bad taste. This affront to the president cannot but hurt the position of the United States during a period of world turmoil.
Lawrence E. Beckley
Winchester, Mass.

### The Moon versus Mars

Carol Stoker and Christopher McKay do a poor job of justifying a manned mission to Mars (*"Mission to Mars: The Case for a Settlement," November/December, page 27*). Funding for such a mission is determined not just by costs but also by the return on investment—in knowledge and materials. A mission to the moon would be far superior to one to Mars, since the moon is airless, has lower gravity, and is much closer to Earth. Lunar soil could be processed to make oxygen, aluminum, and other materials for use in Earth orbit, while martian materials could be used only for a Mars base—hardly a reason for setting one up. Once lunar materials are available, the costs for manned missions to the planets will drop dramatically. Until then, we should be content with unmanned probes.
Paul F. Dietz
Canoga Park, Calif.

Stoker and McKay state that "today's military budget annually is over 10 percent of the GNP." That simply is untrue. NASA proponents may habitually work magic in their cost calculations, but it is unfortunate that one of the few figures that can be independently verified is wrong.
Douglas Karo
Medford, Mass.

*Editor's note: According to U.S. government figures, the annual military budget is slightly less than 8 percent of the GNP.*

### To Qualify Thinking

Marvin Minsky's definition of self-awareness as knowing what is in our own minds is flawed (*"Why People Think Computers Can't," November/December, page 65*). An individual usually takes self-awareness to mean being aware of oneself as an "I." Minsky aptly exhibits his own self-awareness with at least two dozen explicit self-assertions such as "I think," "I suppose," and "I'm sure."

But even if we use Minsky's definition, his conclusion that we don't know what is in our minds is specious. People are not aware of the detailed muscle movements involved with walking, yet we are aware of ourselves as walking beings. Similarly, we may not be aware of the details of our thought processes, yet we are aware of our thinking, and more importantly of the results of our thinking.
Robert G. Mays
Chapel Hill, N.C.

Marvin Minsky fails to explain why experts who maintain that "machines can never be creative, intuitive, or emotional and will never really think, believe, or understand anything" are wrong. The article is peppered with "I'll argue that . . .," "Perhaps . . .," "Everybody knows . . .,"

*(Continued on page 20)*

# How Exxon's advanced the refining of

## FLEXICOKING converts 99% of even the poorest feedstocks into high-quality fuels.

A key challenge facing the oil industry today is to ensure the most efficient conversion of available crude oil supplies into the highest value products. This is increasingly difficult because, while demand is shifting toward light, cleaner-burning products, available crudes are becoming heavier.

In addition, some heavy crudes contain high concentrations of impurities, such as sulfur, nickel and vanadium, so that key catalytic refining processes cannot readily handle them. These contaminants "poison" process catalysts just as lead deactivates an automobile's catalytic convertor. Future unconventional feedstocks, such as bitumen from tar sands and shale oil, are likely to be even harder to process.

### A Powerful New Refining Tool

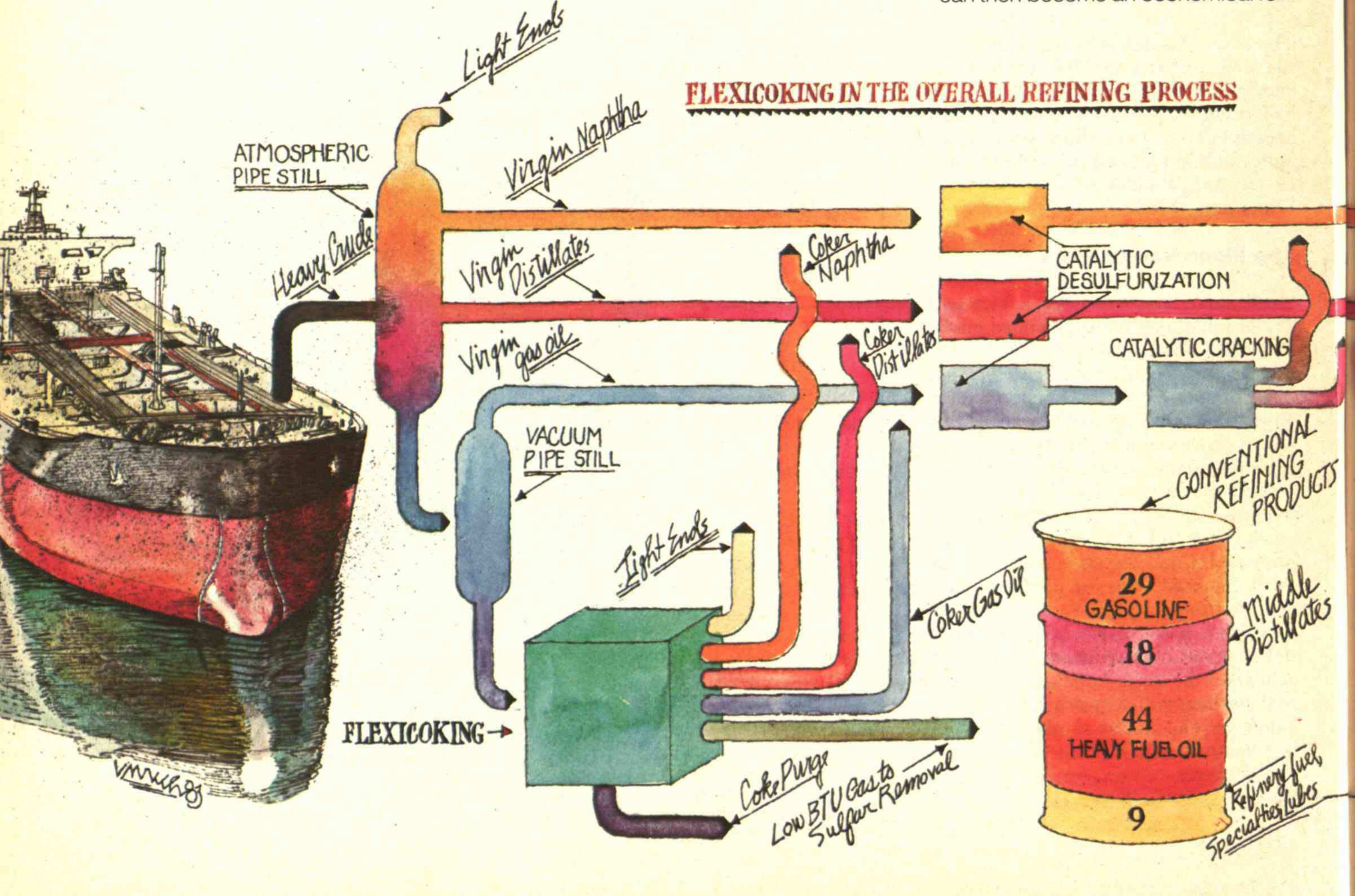
But scientists and engineers at Exxon Research and Engineering Company have a unique solution—an extremely rugged process called FLEXICOKING that converts in excess of 99 percent of the worst possible feedstocks into high-quality liquid and gaseous fuels.

FLEXICOKING relies on thermal cracking rather than catalytic cracking to convert heavy feedstocks to lighter products. Thermal conversion is not new. In the 50's, Exxon developed FLUID COKING to upgrade heavy feedstocks. FLEXICOKING further extends this pioneer thermal process with one major improvement.

In FLUID COKING, heavy feed is sprayed into a large reactor containing very hot, granular coke. The upward flow of hydrocarbon vapors and injected steam suspends the finely divided particles, permitting the hydrocarbons to contact the coke on all sides. The heavy hydrocarbon molecules fracture as they contact the hot coke. This results in additional gasoline and middle distillate liquids. However, about 30 percent of the heavy feedstock is rejected as solid coke, which represents almost 20 percent of the energy in the original feed.

### Replacing Expensive Refinery Fuel

FLEXICOKING represents a key advance by converting the coke into a clean-burning low-BTU fuel gas (LBG) in a separate gasification reactor. This LBG can then become an economical re-



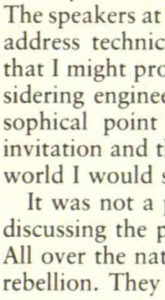
# Existential Pleasures of Engineering: 15 Years Later

ONE evening in late 1968 I received a telephone call from a fellow member of the New York Academy of Sciences. He was trying to round up speakers for the engineering division's monthly meetings, and my name was on his list of prospects. The speakers at these get-togethers usually address technical topics, but he thought that I might provide some variety by considering engineering from a broad philosophical point of view. I accepted the invitation and then wondered what in the world I would say.

It was not a particularly good year for discussing the philosophy of engineering. All over the nation young people were in rebellion. They were attempting to come to terms with their inner selves, seeking to find expression for an ineffable longing that they said was being thwarted by a materialistic society. *The Greening of America* had not yet been written, but its message was being broadcast in a myriad wistful song lyrics and a number of decidedly unwistful, occasionally frightening, student demonstrations.

What are these young people seeking, I asked myself—love and friendship? Many of us seek these first and count ourselves blessed when we find them. Peace in the world and democracy at home? Of course. But as for those other amorphous yearnings of the sixties, they seemed to me unfruitful. Would not the hippie concept of "dropping out" inevitably lead to a dead end? Would not these young rebels more likely find fulfillment in performing work—creative, ingenious and useful work? Does not one come closer to a state of grace by *doing* rather than by simply *being*? Does not the engineer in his daily tasks find, almost incidentally, the very satisfaction that the hippie seeks in vain?

With these thoughts in mind, I delivered a talk entitled "The Existential Pleasures of Engineering." When, some months later, it was printed in the Academy's *Transactions*, I received letters from engineers all over the world. "Yes," many of them wrote, "we, too, have strong, positive philosophical feelings about our profession." Encouraged by this response, I eventually expanded that talk into a book, published in 1976.



SAMUEL C. FLORMAN, a civil engineer, is author of *Engineering and the Liberal Arts, The Existential Pleasures of Engineering,* and *Blaming Technology.*

### The Engineering Instinct

*Existential*—quite a word. Many people asked me why I could not have used a less pretentious-sounding adjective. The fact is I tried, and almost wore out my thesaurus, but I simply could not find a better way to say what I wanted to say.

Existential feelings are those irrational feelings that arise out of the depths of our innermost being—our intuitions, our basic impulses, what we feel in our heart (which as Pascal said, has reasons that reason cannot know), in our bones, and in our gut. What the Orientals mean when they speak of thinking with the belly.



ILLUSTRATION: ELIZABETH SLOTE

*Analysis and practical creativity do not preclude emotional fulfillment; they are paths to such fulfillment.*

Deep down, I believe that engineering is what human beings want to do. Not the only thing, but one of the most basic and satisfying things. Engineering is an activity that is fulfilling *existentially*.

This "technological impulse" helped the earliest humanlike creatures to survive. A better club or a better spear meant a better meal. Craftsmanship and invention contribute to survival of the group, so in most primitive societies these activities are prized and encouraged. Thus, both genetically and culturally this instinct has been nurtured.

As engineers we satisfy other basic impulses: a craving for variety and new possibilities, a feeling for proportion—for beauty—that we share with artists, an impulse to challenge nature—to fight floods and earthquakes—yet also to work in harmony with nature, seeking understanding of soils, metals, and other basic materials of the earth. We partake of the wonders of the natural sciences and enter the pristine realm of mathematics. Our work often contributes to the well-being of our fellow humans. And technology has religious implications—there is a little bit of cathedral in everything we build.

My proposition is that the nature of engineering has been misconceived. Analysis and practical creativity do not preclude emotional fulfillment; they are paths to such fulfillment. They do not reduce experience, as is so often claimed; they expand it. At the heart of engineering lies existential joy.

Fifteen years have passed since I first voiced these sentiments before a friendly, if slightly bemused, group in the New York Academy's elegant townhouse headquarters. In some ways it seems like only yesterday; much of the speech I gave I could happily give again. But in some ways that evening seems to have taken place in another age.

### Ode to an Era

We are now in the no-nonsense eighties, and the flower children are gone. If the truth be told, I miss them—not for their music, drugs, and languid ways, but for the challenge they represented to the rest of us. The young rebels of the sixties were dissatisfied with what America was becoming, and paradoxically their very dissatisfaction was in the best American tradition. Their longing for a better society was an extension of the pioneer's quest. Their search for inner fulfillment was a poignant manifestation of "the pursuit of happiness." Their divine discontent was the same force that animates all worthy human endeavor, not least engineering. Out of the discontent of the sixties grew a more humane technology with more concern for esthetics, safety, and environmental preservation. And among engineers there developed a keener appreciation of the moral importance and creative richness—the existential pleasures—of their profession.

Nowadays, however, we hear little of utopian dreams and more of concern about survival. With an energy crisis, a declining trade balance, and inflation followed by recession, it appears that we are not as wealthy or powerful as we once thought. We are suddenly aware of our limitations—which is all very well—but impatient with idealistic aspirations—which is a shame.

The engineering profession has flourished during the past 15 years, yet in its very success lie the seeds of potential debasement. In 1968 slightly more than 70,000 college freshmen entered engineering education, and the number was dropping precipitously. (It bottomed out at about 52,000 in 1972 and 1973.) Of late the trend has been sharply upward, and the figure now stands at more than 115,000. In the absence of adequate faculty and facilities, the quality of this education must be questioned.

Equally troubling, in my view, is the attitude of the prospective students. In 1968 a study showed that young people chose engineering as a profession mostly because it promised "interesting work"; today the choice is made increasingly because of "job opportunities." In 1968 we were still talking in terms of a Great Society and looking forward to the first manned landing on the moon. Today we are cutting back on social services, worrying about competition from the Japanese, and thinking of space largely in terms of military applications.

### Tuning In

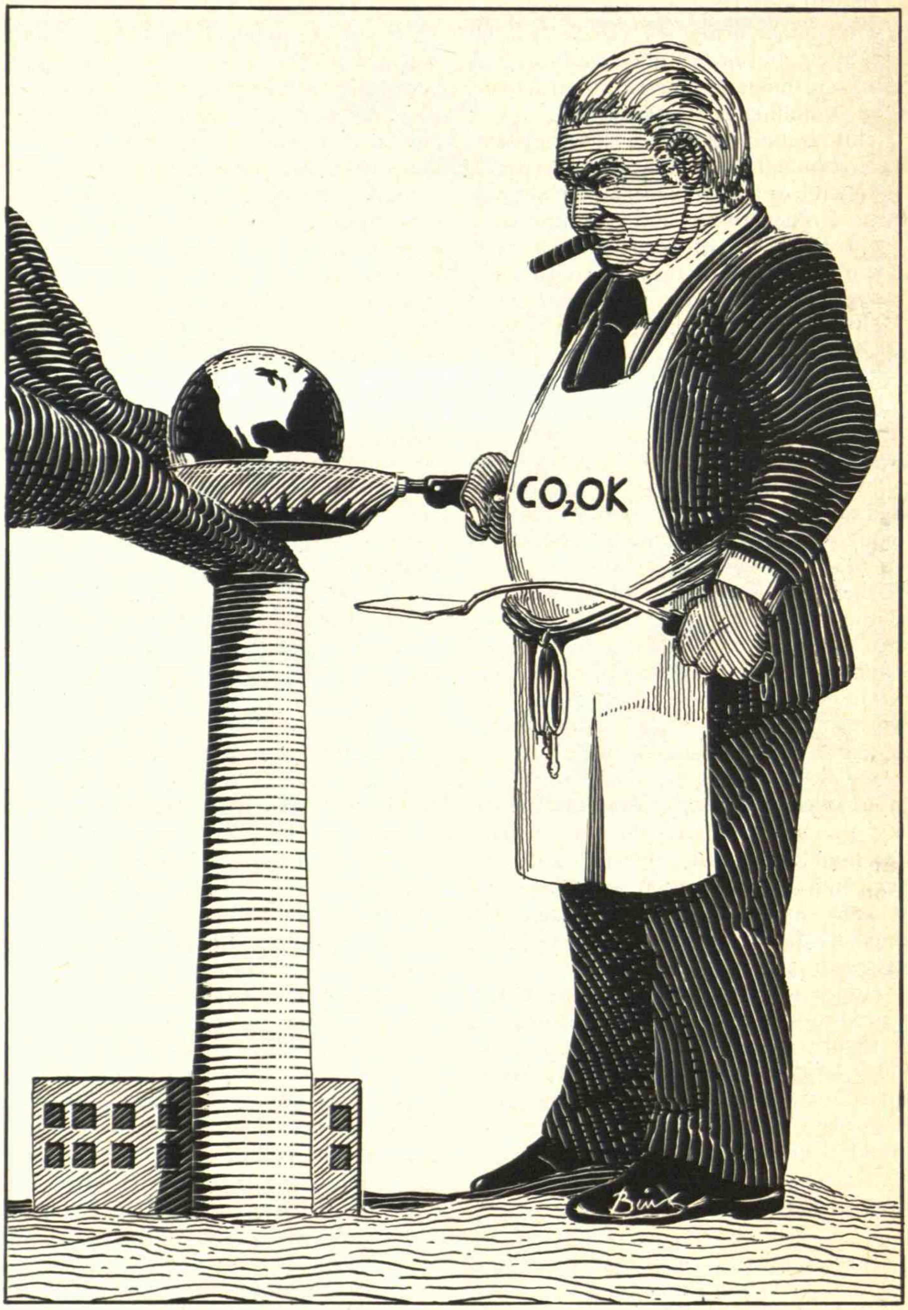
I do not mean to suggest that everything has changed for the worse in the past 15 years—I do not believe this at all. But I am concerned that the quality of the engineering experience may be adversely affected by recent social changes.

The rise of the computer has added to the problem. The phrase "hands on," which has an honored place in engineering tradition used to refer to diesel engines, electric motors, and concrete testing machines. Now those words mean running one's fingers over a keyboard and looking at numbers on a glowing screen. Many people attest to deep-felt, almost mystical, satisfaction in their work with computers. Disputing such assertions is difficult, and I suppose that one ought not to try. "In the thick of active life," as Santayana said, "there is more need to stimulate fancy than to control it." But whatever the benefits and satisfactions inherent in the so-called electronic era, I believe that the age-old physical closeness of the engineer to the natural world has diminished, and regrettably so. Of course, this may just be the civil engineer in me speaking. Be that as it may, the loss of "earthiness" is compensated for by the enthusiasm of many young computer experts. It is the waning of enthusiasm among would-be engineers, the growth of cool, calculating self-interest—in tune with the times, to be sure—that I deplore.

"But," the question has been posed, "if the engineering experience is as great as you say it is, won't it bring out the best in engineers no matter what their reasons for entering the profession?" The response to this is yes, but only to a certain point. The quality of an experience depends partly upon what the individual brings to it. The existential pleasures of engineering are savored to varying degrees by each individual, and I sense that at a time when getting a job is more discussed than the quality of life, these pleasures are less appreciated than they once were.

One of the most popular songs of the sixties was the Beatles' "A Day in the Life." The final line of the lyric was, "I'd love to turn you on," and this was widely assumed to refer to the use of drugs. However, Paul McCartney told a reporter from *Life* that it was intended to mean "turning people on to the truth about themselves." Fifteen years ago I concluded my speech at the New York Academy by referring to McCartney's comment and saying that I hoped all engineers could be turned on to some of the positive truths about themselves and their profession. I believe that the message bears repeating today, perhaps more than ever.□

# The $CO_2$ Threat: Solutions Welcome




CARBON dioxide—which accumulates in the air as we burn fossil fuels—provides colorful imagery for climatic alarmists. Theoretically, its tendency to warm the atmosphere could cause various catastrophes. The melting of Antarctic glaciers might raise sea level and flood coastal cities. Shifts in the rain belts could parch North American wheat lands. The news media love to publicize such scary predictions. But between the doomsayers and the critics who denounce such sensationalism, the real carbon-dioxide ($CO_2$) story is often lost. This is the simple but awkward fact that any climatic threat $CO_2$ may present could be ameliorated by timely action. Arguing about the problem seems easier than searching for solutions.

This point was dramatized—some would say burlesqued—last October when the Environmental Protection Agency (EPA) released its report *Can We Delay a Greenhouse Warming?* The accompanying public statements strongly implied that climatic effects might well show up within a decade, and that drastic action to curb the use of fossil fuels might be needed in this century. Many scientists outside the agency, including presidential science advisor George A. Keyworth II, condemned the EPA for being needlessly alarmist. There was wide suspicion that EPA officials had tried to preempt public attention from a forthcoming National Academy of Sciences (NAS) report on the subject.

The academy report *Changing Climate* released a few days later was much calmer. It urged "caution, not panic" in considering $CO_2$ buildup, stressing the current uncertainties in any scientific assessment of climatic effects. The report recommended waiting for further research before trying to formulate any public policy, including restrictions on the use of coal. This conclusion, incidentally, is also in the EPA report, if not in the public statements surrounding its release.

Thus, within about a week, a climatic horror story promoted by one group of experts was calmly put to rest by another group. No wonder the public loses confidence in scientists! In this case, a subject that needs informed public discussion is likely to be shelved.

ROBERT C. COWEN is science editor of the *Christian Science Monitor* and former president of the National Association of Science Writers.

### Between the Extremes

The prospect of public indifference was too much for Professor David Rose of M.I.T.'s Nuclear Engineering Department. He insists that both the alarmists and the procrastinators have missed the main point of the $CO_2$ issue. He explained that the possibility of $CO_2$-induced climatic change may not be fully understood, but it is credible enough for humankind to begin to explore other energy options. Some $CO_2$ warming may be inevitable, but humanity does not have to burn fossil fuels to the point of inducing a climatic disaster.

Rose bases this conclusion on research



ILLUSTRATION: CHRISTOPHER BING

*A significant global $CO_2$ warmup in the next century cannot be avoided, but we can have some control over the extent and timing.*

he conducted for the National Science Foundation with Marvin M. Miller of M.I.T. and Carson Agnew of Stanford University. The central point of their report, released in January, is that "a significant global $CO_2$ warmup in the next century cannot be avoided, but the extent and timing of it are to a considerable degree under our control."

These researchers point out that both the United States and other nations could begin now to lay the basis for a "$CO_2$-benign" energy strategy—one in which more efficient use of energy, and more reliance on nuclear and solar power, would reduce the need to use coal. The researchers urge starting international discussions on energy use, just as nations are discussing how to control acid rain. Unlike efforts to impose curbs on using coal, such talks should not wait on a better understanding of the meteorology of $CO_2$ pollution.

**The $CO_2$ Cycle**

There are indeed great uncertainties about the possible climatic impacts of a $CO_2$ buildup. To summarize briefly, the atmospheric concentration of $CO_2$ has grown from a preindustrial level of about 276 parts per million to 340 parts per million today. Much of the increase can be attributed to burning of coal, gas, and oil. Forest clearance and loss of organic matter in soil may contribute to the problem. The $CO_2$ that living plants incorporate in their tissue is released when that tissue decays, so a net loss of vegetable biomass can raise atmospheric $CO_2$ levels.

$CO_2$ in the atmosphere absorbs infrared radiation—or heat—from the planet. Some of this heat is reradiated downward, warming the surface and lower atmosphere. This so-called greenhouse effect is not, in itself, harmful, for it helps give the earth its present livable climate. The concern about $CO_2$ pollution is that the warming may be overdone.

Most analysts consider the use of coal to be the crucial factor in $CO_2$ buildup because the world's coal reserves are vastly larger than its oil reserves. As more forests are cleared, significant new amounts of $CO_2$ could also be released, but pollution from burning coal is likely to have the most dramatic effect. The National Research Council of the National Academy of Sciences has estimated that annual $CO_2$ release could well quadruple by the year 2100. The council estimated that there is a 50 percent probability that such releases would be between 12 to 55 billion tons of carbon—a rather large uncertainty level. However, experts generally agree that computer models predicting a possible warming effect of several degrees in the lower atmosphere are plausible.

Beyond this point, scientific uncertainty abounds. No one knows how the global carbon cycle works, or how added $CO_2$ might affect the cycle. Today's computer models cannot simulate with confidence effects such as the mixing of ocean waters, which is important to the $CO_2$ cycle. Until the transfer rates among atmosphere, ocean, and biosphere are better understood, estimates of future atmospheric $CO_2$ levels will be shaky. Also, other gases such as nitrogen oxides and methane increase the greenhouse effect. The role of these gases—which are released by biological activity and the use of fertilizers—in $CO_2$ buildup is poorly understood.

Such uncertainties give alarmists plenty of room to project scenarios for disaster. Yet the possibility of climate trouble is credible enough to encourage us to search for energy alternatives, as Dr. Rose and his colleagues point out, "rather than relying solely on research to narrow uncertainties and ameliorative measures such as building dykes and developing new strains of 'greenhouse-resistant' crops."

It also makes sense to learn how to manage the world's forests better. A research team from the Marine Biological Laboratory at Woods Hole, Mass., and the University of New Hampshire has concluded that careful forest management could help limit atmospheric $CO_2$ buildup. They note in *Science* that "appropriate action taken now might reduce or eliminate the [$CO_2$] problem."

Surely, this is the basic point for public policy. Scientists may not be able to predict climatic trends with any certainty, but moves such as improving energy efficiency and forest management could ameliorate a $CO_2$ buildup and are also worth doing for their own sake. □

# Can We Afford Health Care as a Commodity?

By Arnold S. Relman


## The Controversy Over

STARTING about 15 years ago, soon after the creation of Medicare and Medicaid brought a fresh infusion of federal funds into the health-care economy, a major new industry was born. I call it the "medical-industrial complex" because of its resemblance to the "military-industrial complex" that Dwight Eisenhower warned about as he was retiring from the presidency in 1961. Both complexes are huge, highly profitable, and political influential industries that supply essential high-technology goods and services and depend heavily on federal subsidies.

The medical-industrial complex consists of a large network of for-profit corporations that operate general and psychiatric hospitals, nursing homes, ambulatory surgery centers, walk-in clinics, emergency rooms, renal dialysis centers, home health services, diagnostic laboratories, diet clinics, alcoholism treatment centers, and many other health services. These services were formerly the almost exclusive responsibility of individual or small groups of medical practitioners, or of nonprofit or public tax-supported hospitals.

The new health-care businesses currently own about 15 percent of all the acute-care general hospitals in the country, more than 60 percent of all nongovernment psychiatric hospitals, nearly 75 percent of all nursing homes, and about 40 percent of all dialysis units. Many of these businesses are owned by individual entrepreneurs or small groups of investors, but the industry is becoming increasingly dominated by large, publicly owned corporations, a few of which have gross revenues of several billion dollars a year.

To many hard-pressed communities, selling out to an investor-owned hospital chain seems like an ideal way to modernize or replace an aging nonprofit or public hospital, without having to raise money or increase taxes. Proponents of the hospital corporations point not only to their acknowledged success in raising new capital but also to putative advantages in efficiency of operations and quality of care. However, such advantages have never been demonstrated. There is, in fact, much reason to question the wisdom of turning over hospital care, or any sector of the personal health-care system, to the commercial market. The result could well be a gradual reversion to the two-tiered system of care that existed before Medicare and Medicaid. This system includes one tier for those who can afford to pay and another, less accessible and less adequate, for the poor.

Business investment was inevitably attracted to the health-care sector with the advent of Medicare and Medicaid. These and other systems of third-party reimbursement, which have been the main form of payment for the majority of hospitalized patients since the sixties, virtually guaranteed profits to any hospital owner.

While private, nonprofit hospitals do often generate operating surpluses ("profits"), they have found it increasingly difficult to raise the new capital needed for building and modernizing plants and equipment. Private philanthropy, upon

 ILLUSTRATION: ROB SAUNDERS

# Commercialized Medicine

which many nonprofit hospitals heavily depend, has begun to dry up as a major source of support. Furthermore, high commercial interest rates have limited the funds that can be generated through debt. Tax-supported hospitals have also faced increasing problems in maintaining and replacing their facilities because of rapidly rising costs and growing public resistance to higher taxes.

The investor-owned hospital chains, on the other hand, have had no problem raising new capital by borrowing private funds or issuing stock. Their rapid expansion, and the prospects of large returns on equity, have attracted eager investors in great numbers. These hospital chains have used this advantage to help them acquire and modernize existing hospitals, and to buy smaller hospital chains. The result of such mergers and acquisitions is that the hospital market is now dominated by five or six large corporations.

Unfortunately, empirical evidence on the performance of for-profit hospitals is
*(Continued on page 12)*

## For-Profits vs. Nonprofits: A Phantom Issue

By Frank A. Sloan and Edmund R. Becker

NONPROFIT hospitals have played a vital role in providing health care to Americans for the past 150 years. But over the last decade, the structure of the health-care industry has undergone a rapid transformation. There has been substantial growth in the number of investor-owned, "for-profit" hospitals, many of which belong to nationwide chains. Furthermore, the number of for-profit hospitals is likely to rise during this decade.

The dramatic increase in the number of these hospitals has raised many important questions. As health-care companies expand, will the cost of health care rise? Will the quality of care diminish? Will the poor be denied access to needed services? To what extent will hospital profits be diverted away from teaching and research?

Such questions have become a source of considerable debate, within both the medical profession and the policymaking community at large. Some observers warn that the encroaching "medical-industrial" complex means the end of universally available health care. Others see investor-owned hospitals as a way to control the exorbitant costs of health care and provide reasonably priced care.

The available evidence suggests that neither argument is correct. Some recent studies indicate that there is really not much difference in the economic and social performance of most for-profit and nonprofit hospitals. Costs on a per-admission basis are about the same, and one type of facility is as likely as the other to "dump" poor patients on the nearest government-funded hospital. No for-profit hospitals, and only a small minority of large, nonprofit hospitals, are committed to research and teaching. Thus, changes in the ownership of U.S. hospitals will probably have much less impact on patient care, teaching, and research than other changes, such as the trend toward stricter third-party payment policies by both private and public insurers.

Some of the controversy about profits
*(Continued on page 13)*

*The bill is higher in investor-owned hospitals, mainly because they do more tests and charge more for them.*


## The Hazards of Health Care as a Commodity

*(Continued from page 11)*

in short supply. Making economic comparisons between hospitals is tricky because costs depend on the size and technical sophistication of a hospital, the extent of its teaching and research programs, the economics of the region in which it is situated, the social demography of its patients, and the severity and complexity of the diseases it treats. No comparisons between for-profit and not-for-profit hospitals have controlled for all these factors, or even taken note of them all.

Nevertheless, a few published studies have compared relatively large groups of similiarly sized, nonteaching hospitals in terms of easily measured economic characteristics. These studies, based on data from 1978 to 1981, all show essentially the same thing: the investor-owned chain hospitals are *not* less expensive to operate. Their costs are at least as high as those of comparable nonprofit hospitals, and in some instances, a few percentage points higher. What is more, their charges—and the revenues collected from third-party payers—are considerably higher. Advocates for the investor-owned hospital industry often make statements to the contrary, but no systematic studies in professional journals support those claims. If these advocates have data that can stand up to peer review, they should publish them.

### More Tests at Higher Prices

Two published studies have failed to support the claims of the investor-owned health-care industry. One such study, published in 1981, compared 53 investor-owned hospitals with 53 similar nonprofit ones in California, Texas, and Florida. The researchers at Lewin and Associates in Washington, D.C., found that charges per admission were 17 percent higher for the investor-owned hospitals, and collections of unpaid bills were 12 percent higher. The higher revenues stemmed from higher charges for ancillary services such as laboratory tests and x-rays. Total operating expenses per admission were 4 percent higher in the investor-owned hospitals, yet these hospitals managed to generate a greater net income than the nonprofit hospitals because of their higher charges.

In a more recent study, researchers from the Western Center for Health Planning in San Francisco analyzed data from 114 private nonprofit hospitals, 53 investor-owned hospitals, and 35 public hospitals in California, all comparable in size and services. The researchers found that total inpatient charges per admission were 24 percent higher in the investor-owned chains than in the nonprofit hospitals, while actual collections were about 10 percent higher. The higher revenues again came from the increased use of ancillary services, as well as from higher prices per procedure. The California study also showed that total operating expenses per admission were 2 percent higher in the investor-owned hospitals.

Comparative information on the quality of health care is even harder to find and interpret. The resources and technical capabilities of the for-profit hospitals do not appear to be different from those of their nonprofit counterparts, except that the for-profits use slightly fewer employees per bed. The average length of stay is about 3 percent shorter in the for-profits, but we don't know whether that reflects differences in the nature or severity of the illnesses treated or the speed with which patients are handled. Neither do we have any information about the medical outcome of treatment in the two kinds of hospitals. However, significant differences are unlikely, since the training and competence of the medical and nursing staffs are probably similar.

I suspect that the quality of care at these two kinds of hospitals is much the same. The only difference is that the bill is higher in the investor-owned hospitals, mainly because they do more tests and charge more for them. Since medical practice largely reflects the judgment and professional style of individual doctors, care in investor-owned hospitals costs more probably because they attract physicians with expensive styles and encourage them to use technical procedures. For instance, executives of investor-owned hospital chains will buy any type of medical technology—no matter how expensive or redundant—if physicians want the device and will use it often enough to produce a profit. That includes highly sophisticated NMR and CAT scans, as well as more common diagnostic tests. The chain hospitals also recruit young physicians by setting them up in practice, guaranteeing their initial income and helping them with office equipment and rent. To qualify for this assistance, all the physicians must do is agree to send their patients to the sponsoring hospital.

### An Economic Imperative

Why medical care in the for-profit sector is more expensive is easily understood if we consider the economic imperatives of health-care corporations. To prosper, they must continually expand their net revenues. One way to do this is to acquire new hospitals, but another is aggressively to market and sell profitable services. Everyone knows that an à-la-carte menu is the most expensive for consumers and the most profitable for providers. As long as health insurers are willing to pay charges on a piecework basis, the investor-owned companies will try to sell as many individual items as possible. If, and when, payment for hospital care changes to a system of fixed prices for services, incentives will of course change. Profits will then be made by increasing certain types of admissions, shortening length of stay, and reducing the number and cost of services supplied to each patient. It remains to be seen how the investor-owned hospitals will fare under such a system.

Defenders of investor-owned corporations are fond of pointing out that economic incentives in the nonprofit hospital

*There is not much difference in economic performance between for-profit and nonprofit hospitals.*

sector are not much different. They argue that all hospitals, unless they are tax-supported or can rely on substantial philanthropic support, must generate more revenue than expenses to stay viable. An operating surplus is necessary if any institution, for-profit or not-for-profit, is to accumulate enough capital to maintain and renew its plant. But this argument ignores the fact that profit per se is not the prime economic goal of investor-owned corporations. It is the prospect of an increase in the value of stock that attracts investors, and it is the opportunity to acquire profitable stock options that enriches top management. To ensure that the company's stock will rise, managers must make sure the business continues to grow. This economic imperative dominates the managerial decisions of the investor-owned hospitals, resulting in policies different from those of most nonprofit institutions.

The Florida Hospital Cost Containment Board has published data showing that when for-profit companies purchase hospitals, charges and costs usually rise precipitously. A recent study by the U.S. General Accounting Office has documented the increased costs to third-party insurers (estimated at over $50 million the first year) that followed the purchase of a chain of hospitals by the Hospital Corporation of America.

**Dumping the Poor**

The need to expand net revenues motivates for-profit hospitals to discourage the admission of poor or uninsured patients, and to avoid unprofitable services. When an investor-owned chain acquires a nonprofit hospital, all indigent patients are henceforth shunted to another institution.

In this country, we have always depended on a significant degree of charity and cross-subsidization by the nonprofit, tax-exempt hospitals to provide health care for the poor. Competition from the for-profit sector, which is skimming away a large number of paying patients and profitable services, is impairing the ability of many nonprofit hospitals to shoulder their share of the free-care burden. The shunting of indigent patients to public hospitals already suffering from reduced tax support can only mean deterioration in services and less care for the poor.

An example of this phenomenon can be found in the Tampa Bay area of Florida. As shown in a recent documentary on public television, the Tampa General Hospital, a public institution, is feeling the burden of competition from new for-profit hospitals. These hospitals have been siphoning off paying patients while referring their poor patients to Tampa General. As a result, the financial health of Tampa General—the only hospital in the region that provides free care—is being seriously threatened.

In an effort to survive in an increasingly competitive marketplace, many nonprofit hospitals are adopting the same policy as the for-profits: aggressively marketing their services, charging higher fees, and referring their poor patients to other institutions. However, most indigent patients still receive care in nonprofits—either tax-supported facilities or the large, nonprofit teaching hospitals. Although the large hospital corporations could well afford to provide the same proportion of free care, they don't. Neither do they make much of a contribution to medical research or education. This is particularly disappointing in view of the extent to which they benefit from the new technologies and procedures developed at the teaching hospitals.

If the for-profit system continues to expand, the traditional concept that hospitals are obligated to serve local communities will vanish. Health care will become a commodity distributed largely by a commercial market and ruled by the bottom line. Teaching and research may be considered costly and unprofitable "frills." The success of the for-profit chains could also bring a return to the grossly unequal two-tiered system of health care that existed before Medicare and Medicaid.

Do we want this to happen? Can we afford this new medical-industrial complex? Who will really benefit from the commercialization of health care? These questions require careful examination and public debate. We may be witnessing the beginnings of a new and more efficient system of health care. But we may also be in the midst of an aberration in our social and political history that will sooner or later have to be corrected. □

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## For-Profits and Nonprofits: A Similar Bottom Line

*(Continued from page 11)*

in medicine stems from a lack of understanding about what a "nonprofit" organization is. The key distinction between nonprofits and for-profits is legal. Although nonprofit institutions often make profits, they do not distribute gains to shareholders and cannot raise equity from the sale of stock. In fact, as a group, private nonprofit hospitals in the United States have earned profits every year since 1963, when the American Hospital Association (AHA) first began collecting such data. Indeed, revenues of nonprofit hospitals have traditionally exceeded costs by about 3 to 4 percent.

Nonprofit organizations enjoy some advantages conferred by federal and state governments, including exemption from property taxes, access to tax-exempt bond issues, and eligibility for grants and private donations. Historically, nonprofits have also received preferential treatment in exemptions from the Fair Labor Standards and National Labor Relations Acts, and in the areas of antitrust, Social Security, and pension benefits. These competitive advantages enable nonprofit organizations to engage in some "unprofitable" activities, such as teaching, research, and free

*Competition from for-profits is making it difficult for many nonprofit hospitals to shoulder their share of the free-care burden.*

care for the poor. However, such advantages have declined in recent years. Nonprofits are now subject to major federal labor laws, and some mergers are scrutinized by the Department of Justice. Also, philanthropic donations have decreased, so nonprofits must increasingly be operated as businesses.

### Who Exploits Whom?

Much of the health-care system in the United States is organized on a for-profit basis. Most physicians and dentists practice alone, in partnerships, or as owners of small professional corporations. Commercial insurers control about half of the private insurance market; Blue Cross-Blue Shield and other nonprofit health insurers dominate the other half. All makers of pharmaceuticals, medical devices, eyeglasses, appliances, and hospital supplies are for-profit firms, as are the owners of about three-quarters of all nursing homes.

Profit making in the above industries, except nursing homes, has never been a concern to health professionals or most policymakers. Why, then, is there so much concern over the growth of for-profit hospitals? Critics seem to have two major worries.

First, hospital care is complex and not well-understood by patients. In the view of many patients and health professionals, a profit-seeking hospital is well-positioned to exploit consumers, whereas the nonprofit hospital does not have to produce a profit for its shareholders and thus is under less pressure to exploit. This argument is deficient for a number of reasons. Physicians serve as patients' agents in purchasing hospital care. Presumably physicians, most of whom are not hospital employees, are able to protect their patients. The question of whether doctors do, in fact, protect their patients' interests is a separate and much more important issue.

Critics of the for-profit form of hospital ownership also suggest that physicians guard patient interests when they are affiliated with nonprofit hospitals but not when they work with investor-owned hospitals. This is because in some hospitals, income from admitting patients and ordering hospital services accrues to doctors as shareholders. But except at small investor-owned hospitals owned by one or at most a few doctors, physicians who admit patients for surgery earn much more from the surgical procedures than from the distributed profits from patients' hospital stays. Thus, if there is an important conflict of interest, it is with the fee-for-service system rather than physician affiliation with an investor-owned hospital.

A major justification for nonprofit hospitals is that they use profits from some services to subsidize "unprofitable" but important services such as care for the poor, teaching, and unfunded research. But at least some of the profits made by nonprofit hospitals—as well as by for-profit facilities—are used for investment purposes. Also, the nonprofits' tax advantage now amounts to only about 3 percent of their revenue. Thus, the "average" nonprofit hospital is no longer in a position to do much cross-subsidizing. This diminishing ability to cross-subsidize is apparent when one compares the dollar amount of bad debt and charity care provided by the different hospitals. In 1982, for example, that amount at for-profit hospitals was 3 percent of total hospital charges, 4 percent at private nonprofits, and 9 percent at government-funded facilities, according to the AHA.

There may be another, less obvious reason for the resistance of many medical professionals to for-profit hospitals: physicians may fare better financially with nonprofit than for-profit ownership. When hospitals charge patients just enough to break even, doctors have more latitude to raise their own fees. Henry B. Hansmann, professor of law at Yale, made this analogy in *The Yale Law Journal* in 1980: "It is as if a foundation, tax-exempt and supported in part by public contributions, were to build office space and then lease it at cost, or less, to Wall Street [law] firms. One would not expect to see lawyers in a hurry to have the foundation converted into an ordinary profit-making landlord."

### Similar Economics

Considerable debate has focused on the economic performance of investor-owned nonprofit hospitals. Recently, Dr. Arnold Relman, in an editorial in the *New England Journal of Medicine*, briefly reviewed three studies from the states of Florida, Texas, and California. These studies seem to support the view that investor-owned hospitals are less efficient and more costly than their nonprofit counterparts. Relman recognized that none of the studies alone is definitive, but that together they provide a persuasive description of the average economic behavior of both types of hospitals. Relman concluded that "compared with nonteaching, not-for-profit voluntary hospitals of the same size and in the same geographic areas, the investor-owned chain hospitals have evidently charged patients more per admission, and their operating costs have been at least as high."

### Studies Incomplete

However, the studies have a number of shortcomings. Most serious is the failure to account for differences in wage rates, the mix of patient cases and services, and the source of third-party payments among the various hospitals and locations. Moreover, the overall differences between the nonprofit and for-profit hospitals were sometimes so small that a conclusion of "no difference" would have been more apt.

In a soon-to-be published study, we used a 1979 AHA survey of 2,000 hospitals nationwide to compare the costs and profitability of various forms of ownership. We applied the technique of regression analysis to isolate the influence of an individual hospital's characteristics on its costs and profits. For instance, we accounted for wage rates, the mix of patient cases and services, and the source of third-party payments.

We found that differences in economic performance between government, private nonprofit, and for-profit hospitals were much smaller than previously suggested. Specifically, the results showed that government hospitals tend to be less profitable than either private nonprofit or for-profit hospitals, and that profit margins for both for-profit and nonprofit hospitals are about the same. Furthermore, hospitals that have been part of a multihospital chain for four years or more are less costly to run than hospitals that have been part of a chain for less than four years. Investor-owned hospitals cost more per day, but costs per admission are similar to those of other hospital types because the average hospital stay tends to be shorter.

Quality of care is much more difficult to measure and compare. Among other things, quality depends on the proficiency of the staff in performing specific procedures, the amount of nursing care pro-

*With or without the for-profits, hospital care has become a big business.*

vided, and the amenities of the physical plant. Although many hospitals attempt to measure the quality of their care for internal review, such data are usually not available to outside researchers. Thus, it is difficult to produce conclusive findings. We know of no statistical evidence that one form of hospital ownership yields higher-quality care than the others.

However, there is certainly speculation on that score. We would argue that, if anything, the investor-owned chains have raised quality in many of the communities they serve. They have brought new approaches, technologies, and facilities to some communities, especially in towns previously served by obsolete hospitals. Modernization, however, comes at a cost, and this may well be the reason that per diem cost often increases when an investor-owned hospital chain takes over.

We also found that for-profit and nonprofit hospitals handle a comparable number of Medicaid patients. And neither type of facility bears more than a small part of the burden of caring for the poor. That responsibility is almost always left to the public-funded hospitals and major teaching hospitals. If these hospitals were to close or substantially reduce the number of poor patients they treat, the poor would suffer greatly.

### The "Cash Cow" Is Dying

Public funding may also become the sole avenue of support for our nation's medical research and teaching. The vast majority of U.S. hospitals do not engage in either teaching or research. Those activities are concentrated in fewer than 400 of the nearly 7,000 U.S. hospitals. Tighter third-party payment policies will soon make it difficult for even these institutions to rely on patient care as their "cash cow" for teaching and research. Government funding would certainly allow the public to choose better the type and amount of research it wants. And if the public is unwilling to tax itself for this purpose, then that is a decision the experts must accept.

To help fund medical education, perhaps students from upper-middle-class families should pay more. Doctors' incomes are high relative to those of other professionals, as are the rates of return on investing in a medical education.

With or without the for-profits, hospital care has become a big business. About 5 percent of GNP is now spent on hospital care. Hospitals are among the largest employers in the communities they serve. The average hospital grossed more than $15 million in 1982—not a small enterprise by most standards. And the double-digit growth rate in revenue of both for-profit and nonprofit hospitals is far higher than that of most U.S. industries. Hospitals' business and medical decisions have become inextricably linked, and we can't turn the clock back to a simpler era in which medical care could be provided with little or no attention to the quantity of resources consumed. The challenge is to combine concern for patient well-being with concern for the use of resources.

Our evidence shows that the differences in economic performance between for-profit and nonprofit hospitals are fairly small—certainly far too small to have generated such heated controversy. The public would be far better served if debate shifted from the profit-nonprofit issue to the future of teaching and research, and to the type of health care the poor and near-poor receive. □

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# Futurism, Intimate Computers, and Rural Sociology

## The Sky's the Limit

*The Hopeful Future*
by G. Harry Stine
Macmillan, 1983, $15.95

Reviewed by Jack D. Kirwan

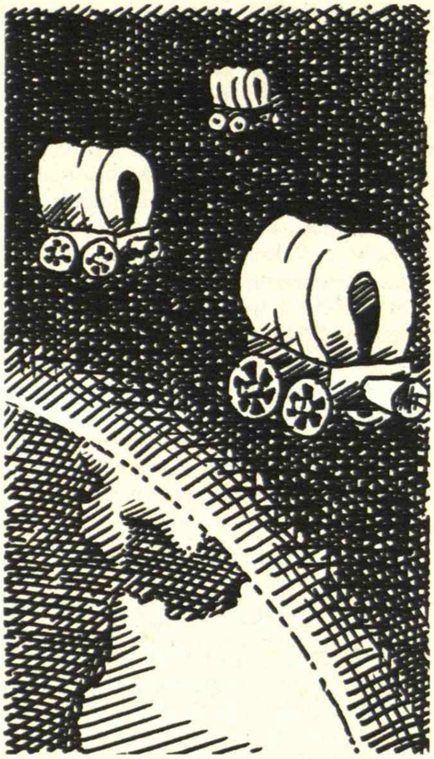
Like handicapping, futurism is a speculative activity that a lot of people work at but few really do well. Pesky variables keep popping up to spoil the beautiful techniques and elegant models. Some futurists try to get around this by playing it safe and practicing "inchworm futurism." They specialize in short-run extrapolations that will occur almost inevitably. Others hedge their bets with assumptions. Exquisite computer models about the future of anything can be made if you assume that there will be no major political movements, economic changes, or technological innovations in the next few years. Although the results of such endeavors can be very tidy, they often bear as much relation to the real world as the papers of the Baker Street Irregulars.

Still other futurists do a Toffler: they latch onto one idea and attack it from all sides for several hundred erudite pages. Last, and most ambitious, are those who risk being tagged "far-out" and "wild-eyed" by tackling the big picture and making sweeping predictions. This approach—the riskiest—is the one Harry Stine has chosen in writing *The Hopeful Future*.

### The Ecological Approach

Stine is an engineer and writer of both science fact and science fiction. Like many who practice more than one of these disciplines, he is an optimist. The book is dedicated to Herman Kahn and Robert A. Heinlein, two technophiles who are noted for their optimism. But, in this not-so-best of all possible worlds, why would anyone be optimistic?

The answer, of course, is not technological but philosophical. Deep down, the optimist basically thinks well of people and their place in the universe while the pessimist does not. During the sixties and seventies, many antitechnologists and no-growth advocates felt that humanity should live "in harmony" with nature—as a passive junior partner. Even the



thought of rearranging nature to satisfy people's needs was seven kinds of blasphemy. Such a viewpoint encourages keeping a low profile and staying out of the way.

For Stine, technology offers an unparalleled opportunity to shape the world (and outer space) for human benefit—if we take an ecological approach. Not the limited ecology of snail darters and obscure lichens but a "systems-engineering" point of view, in which the synergy between technology and culture is a key factor. Stine makes a good case that science and technology too often outstrip social development. "When social organizations are not attuned to the reality of the technology which spawned them, or if social development is not permitted to progress and achieve its potential afforded by the new technology, or if there is insufficient educational discipline in the culture, development goes into reverse. Technology is the first to go downhill, and it is followed shortly thereafter by the downward slide of social institutions."

Stine cites the painful example of the Third World: "Some of the new governments of these nations are having trouble keeping things working . . . because they regressed to ancient forms of tribal or royal governments based more on their old traditional forms than on the organizational structures of the hated colonizers."

Another example is the immigration problem facing the United States. If the Statue of Liberty were put up today, Emma Lazarus' words would read something like this: "Give me your competent and well-educated or highly adaptable people, yearning to acquire radically new skills." The so-called illegal aliens who stream across the Rio Grande are no less hardworking or ambitious than those who left Europe in the last century, but they are usually just as unskilled—a serious problem in a technologically sophisticated society. In contrast to nineteenth-century immigrants, who were needed to industrialize the country, today's immigrants must compete with unemployed U.S. workers for a limited number of low-skilled jobs. The immigration debate is a perfect example of a situation where social institutions are woefully inadequate to deal with the effects of technology.

Stine spends most of the book looking at the key components of a hopeful future—the techniques and technologies that could be used to make the difference between poverty and plenty. For example, Stine makes an excellent case for moving operations up and out into space colonies, believing that space is not just a spectator sport but a participant one as well. He also discusses the myriad opportunities offered by genetic engineering, high-tech forms of renewable energy such as solar power satellites, and social experiments that would enable different regions of the United States to function according to their specific needs. Specialists in any of these areas could complain that Stine treats them rather breezily, which he does. After all, he could have written a fat tome on any one topic. But Stine is painting a mural in broad brushstrokes, not building a mosaic pebble by pebble. He takes a strategic rather than a tactical approach, of which a good deal is speculation.

The most speculative—and to my mind the weakest—part of *The Hopeful Future* is where Stine talks about "psionics"—the marriage of psychic phenomena and electronics. Stine is a skeptical believer in "a number of strange technical devices that work for some people and won't work for others." These contraptions, which violate known laws of science, include perpetual-motion machines and a frictionless drive.



ILLUSTRATIONS: KATHERINE MAHONEY

But when Stine argues that science isn't advanced enough to explain these phenomena, he risks losing his intended audience: intelligent people not already in the choir. Subjects such as neural linkups between humans and computers, space colonies, and doubled life spans are bold but rational extrapolations from today's technology, while much of psionics is, at best, the sheerest guesswork.

Despite this drawback (and a few minor annoyances such as the lack of an index), *The Hopeful Future* will interest anyone whose imagination is not made of boilerplate. To make an omelet, you have to break a few eggs and risk getting some on your vest. By trying to "pluck the roses that grow on the borders of the impossible," as the French say, Stine has created a challenging book. □

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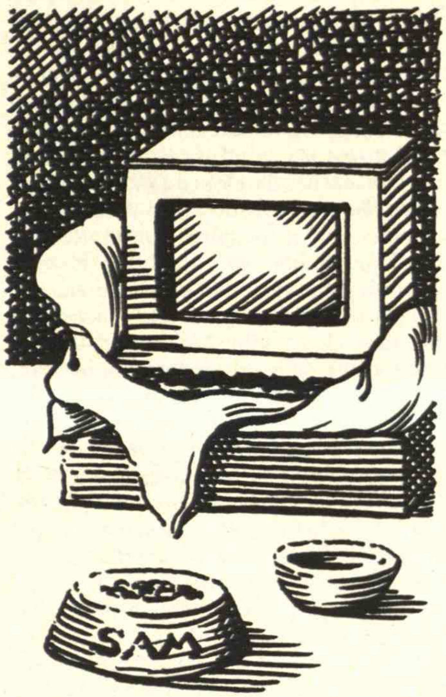
# The Computer as Household Pet

*The Intimate Machine: Close Encounters with Computers and Robots*
by Neil Frude
New American Library, 1983, 234 pp.

**Reviewed by Miles Orvell**

Everyone, I suppose, has kicked a television set to make it work, cursed a flashlight that was dark when you most needed light, and prayed to the god in the engine that the car would start. Nowadays, though, we're communicating more intelligently and purposefully with machines: at the 24-hour bank window, at the computer terminal in the library, at work, and at home, where even the humanist with a word processor is politely informed of his BIOS ERROR and solicited for a course of action. In short, we're becoming more familiar with our machines (especially computers)—possibly even more intimate—and the machine is becoming more "user-friendly."

If we don't like the abstractness of sending directions through a keyboard, for example, we can get a "mouse" to tease the cat. If we don't like the remoteness of the mouse, we can get a computer with a screen we can finger directly. And ma-




chines are already talking to us if we bank by phone or call information in some cities—though their voices are somewhat abrupt and monotone, as if they resent being coerced into speech from their mute electronic slumber. As Neil Frude argues in *The Intimate Machine*, the possibilities for such interactions are endless.

Frude, of course, is well aware of the limitations in the "understanding" of today's machines. Witness this conversation he had with Joseph Weizenbaum's ELIZA, a psychological counseling program devised to study the computer's capacity for speech.

ELIZA: Do you often feel sad?
NEIL: No.
ELIZA: Are you saying no just to be negative?
NEIL: Not at all.
ELIZA: Please don't repeat yourself.
NEIL: I'm not.
ELIZA: Did you come to me because you are not?
NEIL: Not what?
ELIZA: Why do you ask?
NEIL: Now I'm really confused.
ELIZA: How long have you been really confused?
NEIL: Only since I met you.

Despite such experiences, Frude's confidence in the power of machines has not been shaken. What especially interests him, a psychologist by training, is how people think about machines, or rather, how we feel about them.

### The Family Friend

Frude's most pivotal assertion—which he bases on reported research—is that people have a nearly universal tendency to endow the computer with personality and will. "It won't let me do this," we say, or "it wants me to press this button now." Indeed, we often converse with computers with an openness that rivals our willingness to talk with people. For example, we may feel more relaxed about revealing intimate medical and psychological details to a machine than to a person. What happens is akin to a fictional suspension of disbelief, in which we accept the "reality" of a novel or movie and form an emotional bond with the characters. Frude does not try to explain this phenomenon, except to observe that people's tendency to attribute human characteristics to rocks, trees, stars, animals, and mountains is as old as humanity itself. We may be moving into a brave new world of computerized interlocutors, but we're carrying into it our inalienable habit of personifying things.

Still, maybe there should be a limit to how seriously we talk to machines and to how much confidence we place in them. When Weizenbaum observed people—including those who should have known better—relating to the ELIZA program as if it were a real person, he grew alarmed at the ethical implications and considered not publishing the program. And Frude points out the "sinister" potential for Orwellian totalitarianism made possible by programs with subtly embedded political viewponts. But these spectres do not overly concern him: *The Intimate Machine* is mainly a celebration of the possibilities of human-computer interaction.

Leaping beyond present technological limitations, Frude imagines not only educational and counseling uses for computers but also robots that can satisfy a wide range of other human needs. We will be able, Frude says, to order a machine with a customized level of conversational intimacy, wit, empathy, and knowledge—a machine that will be a wonderful social partner. Always willing to listen to what we are saying and to offer sage advice and

support, always there to remind us in a friendly way about our health goals ("How 'bout trying to skip that next cigarette, Jack?"), always ready with an entertaining family story or a joke—the home robot could do just about anything, even engage in extraordinarily satisfying sexual intercourse. Such machines will gain our warm friendship and trust, Frude predicts, and will be of great value to the lonely, the handicapped, the elderly—to all of us, really. They will be versatile household pets, with one cute humanoid machine acting as sentry, butler, teacher, friend, accountant, and spouse.

What are we to make of all this?

I considered the possibility that this book was written by a sophisticated computer seeking to promote its race, or that the book was intended to be a hoax. Then I speculated that Frude might be right: that if people learn how to make such machines at some point in the future, then we undoubtedly will make them, it being the law of human progress that anything that *can* be done *will* be done, especially if there's a market. And in the age of the Cabbage Patch Doll and the Care Bear, who will deny there will be a market? We want, it seems, to give ourselves over to something that will care for us and that we can care for, especially if it's not human.

I finally concluded that I am just a 40-year-old fuddy-duddy trapped in traditional values, still thinking that relationships with human beings ought to receive our primary attention, that satisfaction derives from feelings of autonomy and love. Where's my spirit of inquiry? Where's my thirst for progress? Where's my respect for the technological imperative?

### Only a Tool

However, in his rush to glorify the future, Frude neglects to consider some fundamental issues. Will people adopt robots as friends and counselors, or will the pervasive presence of machines in our lives violate some basic requirements for human satisfaction? And how will computers change our values, beliefs, behavior? For example, if people can choose "intimate machines" programmed according to their own religious beliefs, will this not significantly alter religious experience, and maybe also people's view of humanity's place in the universe?

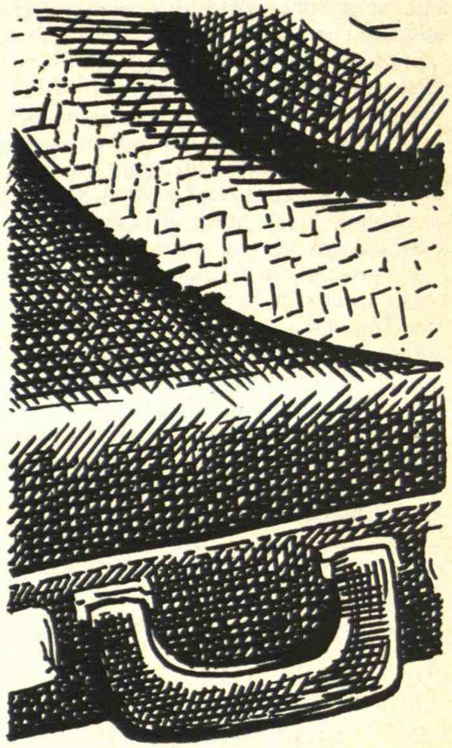
Underlying Frude's vision is a belief that an ultimate harmony exists between human and machine, a belief that seems, in 1984, oddly simplistic. For while in the nineteenth century groups such as Shakers and capitalists, who otherwise opposed each other, viewed the machine as a powerful force for good, late-twentieth-century society has developed a more complex view. We may all still agree that the machine is only a tool that can be used for good or ill, but the particulars of what constitutes good and ill sharply divide us.

For example, when Frude talks about the marvels of industrial robots—about their being able to perform unpleasant jobs nonstop 365 days a year—he celebrates the machine's capacity to increase productivity and profit. But when he easily dismisses workers from employment—"The man, of course, is without a job, but that's another story"—we must wonder whose interests the wonderful machines are serving. It's not that workers should perform unpleasant jobs; rather, that work, in the present order of things, is an economic necessity. It may even be a psychological necessity, essential to a healthy sense of self. And unemployed workers can't go home to a robot-friend-therapist because they can't afford one. Instead, they're wondering how they're going to retrain for jobs that may become obsolete soon after they're created.

Our society is in a period of transition, then, in which we have not sorted out the economic consequences of using robots but are introducing them anyway. As for the psychological and social effects of "intimate" machines, I know only that while I would prefer to talk to some machines rather than to some people, on the whole I'd rather converse with my friends. And I'd have to express the same preference for humans with respect to sex. I suppose there's nothing wrong with living in a mixed universe, one where we share connections with machines, as long as we don't settle for less than we could have in the belief that technology is giving us more. That has been our consistent failing: we put up with the inanities of commercial television because we've got remote control to switch the channel.

Frude's provocative yet superficial book gives us a glimpse of the future without considering the implications for human psychology. I'll have my reading machine scan his next book, which is on robots. □

*Miles Orvell is associate professor in the American Studies Program at Temple.*



## Rural Sociology

*Technology and Social Change in Rural Areas*
Gene F. Summers, ed.
Westview Press, 1983, 266 pp.

**Reviewed by Stephen Budiansky**

The invention of the horse-drawn hay mower in the nineteenth century dramatically increased the amount of land one farmer could reasonably cultivate and decreased the amount of labor needed to do so. This innovation also disrupted a centuries-old interdependence among neighboring farmers, who had joined to harvest, by hand, each farmer's field in turn.

The technological transformations that have swept down upon farmers since then—including hybrid corn, chemical fertilizers, tractors, combines, and pesticides—have likewise profoundly altered the social structure of farming and rural communities. As mechanization has reduced the demand for long hours, farming has become more a business like any other. At the same time, opportunities to enter

farming have dropped sharply: today less than half as many farms exist as just 30 years ago. The average farmer must invest over $300,000 in land and equipment to see a reasonable return. Corporate control of farming, while still a minor overall element (nonfamily corporations own less than 2 percent of all U.S. farmland), has also profoundly altered certain sectors of the farm economy. For example, the broiler industry is 98 percent vertically integrated; once-independent farmers are now contract "growers" who receive chicks, feed, and precise management techniques from Frank Perdue. Even the changing appearance of the countryside, which looks more and more like any suburban subdivision, and the farm bloc's loss of political clout are symptomatic of the social upheaval of American farming.

Of course, mechanization has eliminated the worst of the pure drudgery that was once the farm family's lot. Anyone who doubts that should be issued a scythe and made to cut a five-acre hay field. Technological progress has also lowered food prices and eliminated some exploitive farm labor practices. But many recent technical changes seem to have altered the structure of farming without providing any compensating benefits. For instance, most observers assert that farmers expand their operations to take advantage of economies of scale. However, careful studies show that farms significantly smaller than average attain almost all economies of scale. Expansion, driven partly by the need to pay for larger and more expensive machinery, has become the means to maintain income in the face of shrinking profit margins. The dairy industry is perhaps the most striking case in point. Many dairy farmers have increased their herds to maintain income as profits per cow have fallen. Yet taken as whole, of course, such actions are ludicrously inefficient.

Agricultural economists and rural sociologists could help us understand these problems and the role of government policy in creating or ameliorating them. For instance, do farmers buy larger tractors because of a shortage of labor? Because they have bought land from a neighboring farmer who went out of business? Because of favorable tax credits? Because it's a status symbol? Each of these plausible explanations has profoundly different implications for policy—and even for whether policy can make a difference.

Unfortunately, rural sociologists too often refuse to deal with such practical issues, preferring theoretical, and ultimately self-indulgent, excursions. I'll never forget a paper given by a rural sociologist at last year's AAAS meeting, in which he concluded that the real trouble with agricultural research is that scientists are governed by logical positivist rather than normative values. (The solution, presumably, is to attach a rider to the Department of Agriculture budget forbidding the use of federal funds in a logical positivist manner.) The collection of essays in *Technology and Social Change in Rural Areas* offers much of the same. The first authors set the tone with a discourse on the sociology of rural sociology—or why rural sociologists study what they do. And another author attempts to elucidate the fundamental laws governing public protests against technology by tabulating the articles indexed in the *Reader's Guide to Periodical Literature.*

**Return to Reality**

So much for the theoretical pretensions of these social scientists. What about their effort actually to describe the social effects of technology? Unfortunately, here again the authors disappoint. The standard of proof for their assertions would get them fired from a small-town newspaper after a week. We read, for example, that "the drive for efficiency" has resulted in fewer farms, "often" involving corporate ownership. However, according to statistics of the Census of Agriculture, "often" is used here in the extraordinary sense of one-tenth of 1 percent. And in a somewhat irrelevant essay on the "Social Control of Biotechnology," the author informs us that the U.S. Army asked the National Academy of Sciences to conduct "experiments" on using recombinant DNA to make biological weapons. What the army actually commissioned was a literature search. I wonder if the author realized he was implying that the army was violating an international treaty against developing biological weapons.

Only in two essays do we return to reality. Peter Dorner uncovers several reasons for farm expansion. For example, he points out that some farmers expanded their operations in the 1960s and 1970s so that their children, whose income expectations were rising, would want to take over the business.

Frederick Buttel also provides a hard-headed look at the growing split between large farms, which are capturing an ever-increasing share of the market while relying on hired labor and rented land, and small farms, which are almost exclusively part-time operations. He poses some tough questions for those who would "save" the family farm through price supports, which by their very nature inflate land values and thus disproportionately benefit the largest farms.

One can only hope for more such efforts by rural sociologists, who must start addressing the questions that policymakers desperately need to have answered. □

*Stephen Budiansky is Washington correspondent of the British journal* Nature.

*(continued from page 3)*
"Maybe . . .," "I think . . .," and countless other unproven premises. For speculation and entertainment that technique is ideal. For proving experts wrong, it is bad form.
George Koch
San Francisco, Calif.

By the time we learn more about common sense—knowledge that can then be programmed into computers so that they can "think" as well as or better than humans do now—we who have mastered what common sense is will be ahead of the computers by that much.
Tom J. Ballen
Portland, Ore.

### Avant-Garde Journalism

Robert Cowen's "Avant-Garde Science Journalism" (*January, page 6*) is persuasive. I agree that it is time for scientists and the public to confront each other. Without an informed public, social issues involving science will probably be resolved inappropriately. Pioneering journalists must bridge the gap between scientific advancement and public understanding. Cowen does a real service by helping to bring to the attention of *Technology Review* readers the complexity as well as the importance of this task.
Leo Uzych
Wallingford, Pa.

### An Unmarketable Fusion Program

The long-term possibilities of fusion energy should be distinguished from the prospects for the Department of Energy's current fusion program. Lawrence M. Lidsky (*"The Trouble with Fusion," October, page 32*) may have done a disservice to the cause of fusion energy by failing to make that distinction clear.

As Lidsky says, there is abundant evidence that DOE's fusion program is leading to a product that its only customer, the electric utilities, will not care to buy. Recent design studies of fusion power plants, based on DOE mainline concepts, have clearly shown that costs and operational problems are far worse than for any current, competing technology. Utility engineers are uniformly appalled at the prospect of operating devices such as the tokamak and the tandem mirror.

Through historical accident, conservatism, and a lack of vision, the DOE has sacrificed the long-term prospects of fusion energy to achieve an intermediate goal: scientific breakeven, or net power production from a plasma. However, as Lidsky pointed out, there is a wide range of advanced fusion fuel cycles, some with characteristics far more attractive than the deuterium-tritium fuel cycle of the DOE program. There are also many alternate concepts for magnetic confinement, some of which have engineering and/or economic advantages over the tokamak and

the tandem mirror. These long-term alternatives are not being sufficiently cultivated by the DOE, as evidenced by the effort and resources being devoted to the tandem mirror and tokamak concepts.

In a recent study, Paul Hayman and I compared, I believe for the first time, the mainline and alternative approaches to magnetic confinement. We based our work on a study in which the DOE compared different magnetic-confinement approaches according to three major criteria: confidence in physics, confidence in technology, and overall reactor desirability. We found that the conventional tokamak and tandem mirror ranked second and fourth, respectively, out of 17 confinement concepts in the physics category. This relatively high ranking of the mainline approaches makes sense in view of the enormous amount of time and effort devoted to them over the years.

However, an entirely different picture emerged in the category of technological feasibility. The conventional tokamak ranked sixth out of 16 magnetic-confinement concepts, and the tandem mirror ranked thirteenth out of 16.

We found an even more disturbing result for the category of reactor desirability. The original study approximated the extent to which each confinement approach could be used to make a desirable fusion reactor for the electric utilities. We found that the conventional tokamak ranked twelfth out of 16 concepts, and the tandem mirror ranked at the very bottom.

A number of improvements can undoubtedly be made on this initial study. However, our results reinforce Lidsky's contention that something is very wrong with the power plants likely to evolve from the mainline concepts now being funded by the DOE.

Why are researchers in today's fusion program developing a product so little wanted by the electric utilities? One reason is that the utilities have not been sufficiently involved in the fusion program. One looks in vain for utility executives or engineers on the advisory panels that established the direction of the program.

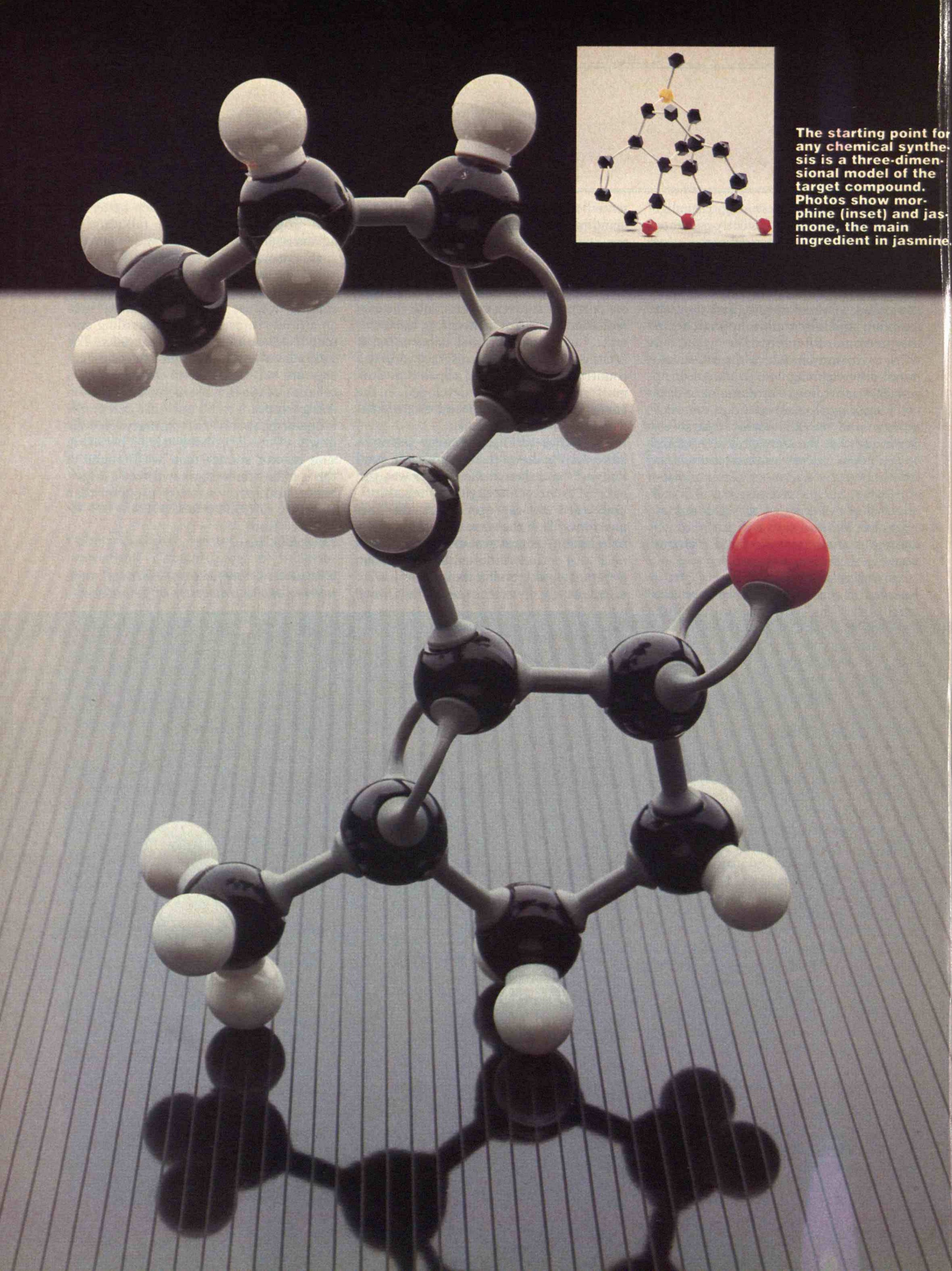
Another reason for the present state of the fusion program may be fiscal conservatism. Many program managers in the Office of Fusion Energy appear unwilling to gamble public R&D money on magnetic-confinement concepts whose physics are less well understood than those of the mainline concepts. The result is that essential elements of the physics of the two mainline approaches were developed in the Soviet Union. The tokamak was, of course, developed by Lev Artsimovich and his colleagues. And after being initiated in the USSR, the Ioffe minimum B magnetic-containment concept evolved into the current tandem-mirror concept at the Lawrence Livermore National Laboratory. It is either unfortunate or disgraceful that a country as inventive and capable as ours must rely on concepts developed in the Soviet Union because of undue conservatism and insufficient funds.

The Office of Fusion Energy seems to have first asked "is the physics well known?" and then, if the answer was yes, asked "is it technologically feasible?" Only then did the agency ask the final question: "Will the concept make a desirable fusion reactor for the electric utilities?" An entirely different kind of fusion program would result if the questions were asked in the inverse order. The United States would likely get a much better fusion program exploiting the full range of advanced fusion fuel cycles and magnetic-confinement concepts.

I hope that people outside the fusion community will not become unduly pessimistic because of Lidsky's article. Such an attitude is justified only regarding current DOE mainline fusion concepts. The stakes involved in the future of fusion energy are very large. With the recent cancellation of the U.S. breeder reactor, fusion energy appears to be our only acceptable long-term option for primary electric power. We will probably need a better fusion reactor sooner than we thought. If this is to be achieved, we will need a larger, better, and more visionary program than currently offered by the DOE.

J. Reece Roth
Knoxville, Tenn.

*The writer is professor of electrical engineering at the University of Tennessee.*



The starting point for any chemical synthesis is a three-dimensional model of the target compound. Photos show morphine (inset) and jasmone, the main ingredient in jasmine.

# Synthesizing Chemicals by Computer

SYNTHETIC materials dominate our modern world. Plastics and other artificial products have replaced natural substances in thousands of applications, from automobile parts to clothing. Even the natural materials that remain, including metal, wood, paper, and cloth, are often coated or colored with the products of laboratory chemistry. Most of us owe our health, and many of us our lives, to synthetic drugs that did not exist until recent decades. And virtually all the colors that we see around us were unknown a century ago; we live in a far brighter world today than did our great-grandparents.

A huge industrial network has grown up based on the ability of organic chemists to transform existing substances into additives, adhesives, coatings, fibers, perfumes, pesticides, pharmaceuticals, pigments, solvents, plastics, and other synthetics. Over the years, chemists have synthesized more than 8 million compounds. Today the chemical industry offers almost half a million for sale. The overall result has been nothing less than a new, synthetic, nature imposed on the old.

In theory, organic synthesis is straightforward. Organic chemists seek to convert about a dozen or so simple compounds, most derived from petroleum, into a myriad of final products using a veritable catalogue of chemical reactions. Just about any compound that chemists can imagine can be synthesized if supplies of starting material are available. However, the final product must be built up stepwise in a sequence of reactions, a process that can be lengthy and laborious. But the real problem is that scientists can envision a vast number of such reaction sequences, so choosing which is best is difficult.

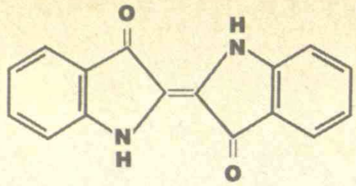
The secret of commercially successful, and intellectually satisfying, synthesis is to find the most economical and elegant reaction sequence. That means discerning the one that produces the maximum amount of the desired product in the fewest steps, and starting with the least expensive materials. Even then, finding how best to synthesize a certain compound is no guarantee of success. Often scientists must synthesize 10,000 substances, each the product of much time and effort, before coming up with a single pharmaceutical tailored for safe, effective medical use.

Can the process of creating useful new synthetics be simplified? The basic ingredient of the problem—the necessity of choosing from among a huge number of reactions and reaction sequences that might lead to the goal—points unerringly to computerization. What computers do best is to select the best options from among many alternatives much faster than humans can. In fact, researchers have been developing computer programs for synthesizing organic chemicals for a decade and a half. These rudimentary efforts are now beginning to jell into the prospect of fast, convenient routes to completely new chemical compounds.

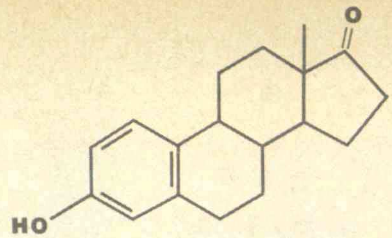
BY JAMES B. HENDRICKSON

Computer programs that help organic chemists synthesize drugs, dyes, and other complex compounds are growing in number and quality. But few chemists so far are willing to accept this machine aid.

PHOTOGRAPHS: BRUNO JOACHIM; SILAS SIMA (INSET)



Indigo
($C_{16}H_{10}N_2O_2$)



Estrone
($C_{18}H_{22}O_2$)

Organic chemistry is so pictorial that it just doesn't express itself in mathematics. As a result, it is a rare organic chemist who has any contact with, or background in, computers. Furthermore, organic chemists are jealous of their intuitive understanding of synthesis. Not surprisingly, they do not welcome the prospect that computers will blithely indulge in the thought processes that scientists acquire only after years of training. Chemists strongly resist signs that organic synthesis will go the way of chemical analysis, which today is largely carried out by computerized equipment.

**From Dyestuffs to Drugs**

Synthesis began in the middle of the last century. Starting with substances available in nature, chemists set out to understand the molecules that comprised them, and then tried to create them out of simpler available chemicals. Compounds of particular interest included morphine, which was purified from opium; quinine, which was derived from cinchona tree bark; and indigo, which was extracted as a dye from a plant cultivated in India. In the late 1800s, after chemists elucidated the structure of the indigo molecule, they synthesized the compound so successfully and economically that artificial indigo (which is identical to the natural) displaced the natural source. That was just as well. If all the indigo we now use to dye blue jeans were still obtained from the plant, we would have to put half of India under cultivation! Other plants such as the rose madder also went out of cultivation when their natural pigments were synthesized.

Those first commercial triumphs of organic synthesis were quickly followed by even greater successes: the production of entirely new dyestuffs. The famous dye mauve, synthesized from simple ingredients distilled from coal tar, exploded on the fashion world of the 1890s as a color never before seen in nature. A whole spectrum of new, synthetic colors rapidly began to emerge from the dyestuffs industry, created first from coal tar and later from petroleum compounds.

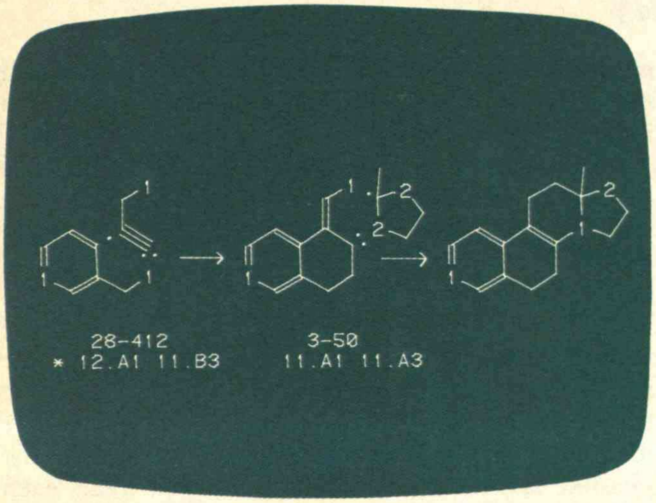
In medicine, the process worked the other way round. Most of the natural medicines from plants were so complex that they were not synthesized until well into this century. But starting about a century ago, entirely new medicines began to appear that were completely synthetic. Aspirin and antipyrine relieved pain and fever. Novocaine replaced cocaine as an anesthetic. And salvarsan provided some relief for victims of syphilis, which had proved untreatable by natural medicine.

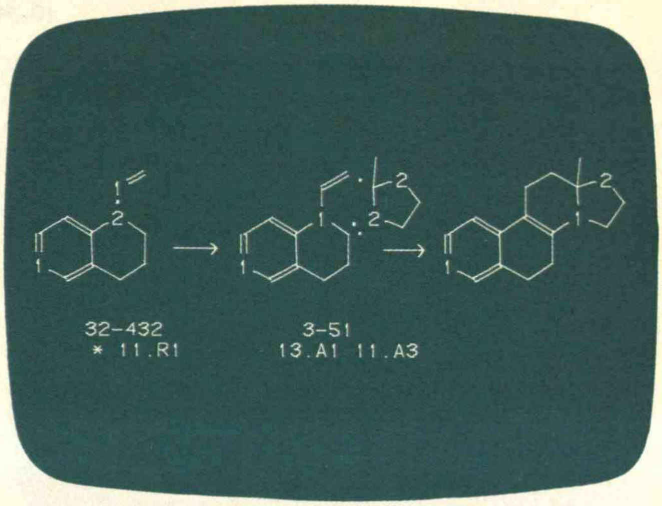
Today, synthetic medicines form a major part of the pharmacopoeia. Natural products from animals, such as estrone and cortisone, must often be synthesized to provide enough for widespread use at an economical price. Partially synthetic forms of natural compounds, such as fluoro-steroids and hybrid penicillins, play major roles in treating disease. And totally synthetic drugs with no prior roots in nature, such as valium and librium, greatly aid the practice of medicine.

**Molecules and Reactions**

The abundance of synthetic products is made possible by the nature of the molecules that make up organic chemicals. Each organic molecule is based on carbon atoms, generally up to 30 in number, linked together by chemical bonds. Four bonds spread out from each carbon atom. Some of these bonds are used to link the carbons together in a backbone, or skeleton, of the molecule. Most of the rest go to hydrogen atoms, which have only one bond apiece. Occasionally carbon bonds join up with atoms of oxygen, nitrogen, sulfur, phosphorus, and halogens such as fluorine and chlorine. These atoms—individually and in combination—are known as functional groups.

Organic chemists picture their molecules in three ways. The simplest is a formula that merely counts the numbers of each kind of atom. Ethyl alcohol—the type we drink—is $C_2H_6O$, for example, while indigo is $C_{16}H_{10}N_2O_2$. Because the atoms in organic molecules can be linked up in many different ways, however, the same formula can refer to a number of substances that have differently bonded structures. For example, the formula for rubbing alcohol, $C_3H_8O$, is the same for two other liquids as well. Thus, chemists frequently draw pictures of their molecules using the letter symbols for elements to indicate specific atoms and lines to show the chemical bonds between them. Even that representation isn't perfect, though, since molecules occupy three-dimensional space. The four bonds of the carbon atom jut out symmetrically like the prongs of a four-pointed jack. Since drawings cannot capture that perspective fully, organic chemists often assemble




**The SYNGEN program has invented an entirely new way to synthesize estrone. The sequence shown here uses four bonds to link three molecular skeletons. While chemically promising, the synthesis has yet to be tested in the lab.**

**Part of an existing synthesis of the sex hormone estrone, as reproduced by SYNGEN. Three reactions, shown by dots, link three molecular skeletons to form an intermediate compound that is later converted to estrone.**

three-dimensional models—either real or computer-generated—to help them understand how chemical reactions take place.

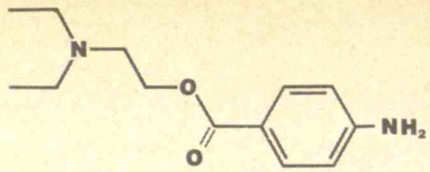
Reactions between different molecules aren't at all inevitable. Most pairs don't react when they meet. Many combinations react only when heated. Paper will not burn—that is, react with the oxygen in the air—until the temperature exceeds 250°C. Other reactions do take place at room temperature, or lower. White phosphorus bursts into flames spontaneously when exposed to air.

When reactions do take place, two processes occur. Existing bonds break, and new bonds form to create new molecules. Two types of reactions are useful for synthesis. Construction reactions join two molecules together by creating at least one new carbon-carbon bond. Such reactions are essential for building up relatively complex synthetic molecules from simple starting materials. Refunctionalization reactions change only the functional groups attached to the carbon skeleton rather than the skeleton itself.

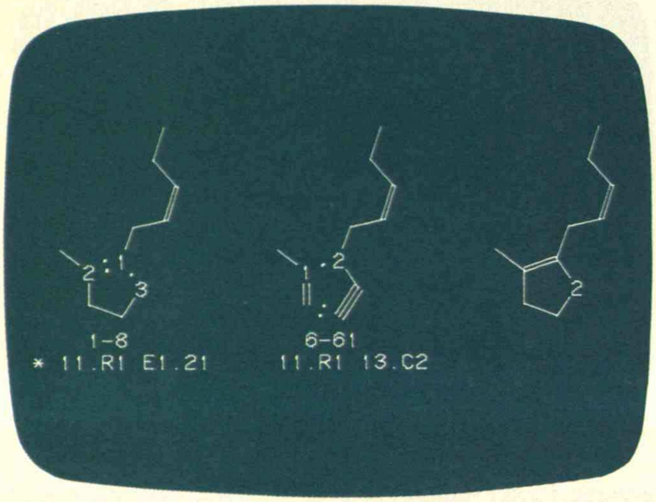
Organic chemists seeking to synthesize specific compounds must cope with various difficulties. The first is the enormous diversity of organic chemical reactions. In moving from a set of starting materials to a desired end product, the results of one reaction become the raw materials for the next. Also, small changes in molecules can cause vast differences in the way they react. Substituting one group on a carbon skeleton can alter the products of a simple reaction entirely. Then, too, organic chemicals rarely react simply. Different reactions occur at the same time in a chemical competition whose results are hard to predict accurately. Finally, even the most dominant reaction rarely succeeds right down to the last molecule. Some reactions carried out at their optimal temperatures can produce 80 percent of the theoretical yield of the expected product; a few do better, but most are worse. So a synthesis scheme that calls for ten reaction steps cannot be expected to produce more than one-tenth the amount of the product it would yield if every step worked 100 percent successfully.

In conceiving a synthesis, organic chemists therefore generally start with the target compound and work backward. Each product along the route back to suitable starting materials can be seen as the result of several possible reactions, each of which means using different molecules one step earlier along the chain. The possibilities multiply spectacularly as chemists push back to reactions that involve simple starting compounds costing little money.

No literature exists to advise chemists how to select the right route from the vast tree of choices. This



**Novocaine**
**($C_{13}H_{20}N_2O_2$)**




**The SYNGEN program has devised two methods (left, center) for generating jasmone (right). Dots in the structures show chemical bonds to be formed; their numbers indicate the order of formation. Reaction notations produced by the program appear beneath the structure.**

route remains essentially intuitive and usually depends heavily on the individual chemist's practical experience. Scientists regard synthesis plans as their own works of art, describing the better ones as "elegant"—although no criteria of elegance have ever been established. Certainly, elegance alone does not guarantee commercial acceptance. Morphine, for example, has been made in a dozen ways; many are only minor variations while some differ significantly from the rest. Even the shortest route, which requires 15 steps, is not used commercially because it is still cheaper to purify natural opium. Researchers have also published about 50 different routes for synthesizing jasmone, the main ingredient in jasmine scent, using between 2 and 15 steps from simple, available chemicals.

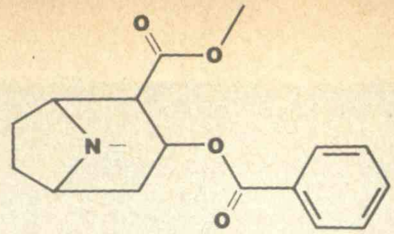
## Enter the Computer

Can computers help chemists discover the best synthesis routes? Some scientists who think they can have laid the basis of programs to design syntheses systematically. These efforts can be divided into two general approaches, known as information-oriented and logic-oriented systems. Information orientation demands a computer database that contains extensive details on known chemical reactions. Logic orientation, which can be subdivided into chemical and mathematical logic, attempts to generate chemical reactions from scratch.

Information-based programs came first, pioneered by E.J. Corey and Todd Wipke at Harvard in the late 1960s. These scientists have since continued their work separately, Corey producing a program known as LHASA and Wipke contributing SECS. Those and other information-based programs use the computer to scrutinize its database for all the reactions that can create the functional groups in the target molecule. By doing this, the computer identifies every compound required to initiate the possible last reactions. The system then treats each such intermediate in the same way as the target compound, moving backward through the synthesis tree one reaction at a time until practical starting materials turn up. In noninteractive forms of this approach, the computer uses the available information to predict the yields of all the reactions that it identifies, and selects those routes with the best overall ratings. In the more popular interactive forms, the chemist uses the computer to list the possibilities at each stage, and then selects the routes and reactions he or she regards as most promising.

The major task in setting up information-oriented programs is supplying them with the library of reactions on which they base their decisions. This library must be built up from reactions written in mixed "chemical-English" format for translation by the computer. Seven firms in Germany and Switzerland have joined forces to build a common database. All chemists in the participating companies are invited to submit reactions to the library, which now lists more than 4,000.

Although it is most advanced in terms of practical use, the approach has several serious shortcomings. First, the number of precursors produced for the target, or for any intermediate down the tree, is considerable. After a few levels of the tree, the choices can inundate the operator and force him or her to undertake heavy pruning. The chemist does this by comparing the predicted yields of different reactions. Unfortunately, the predictions are only educated guesses and can vary widely from the real figures. In fact, the data that go into the computer are inevitably the subjective choice of the chemists who enter it. Efforts to improve that situation, by including more and more reactions in the database, only increase the number of choices available at every stage,



**Cocaine**
**($C_{17}H_{21}NO_4$)**

and hence the uncertainty. And in any case, the library can contain only reactions already known; thus, the program cannot stimulate the invention of new chemistry.

Another concern is that the information-oriented approach is unfocused. Its step-by-step method does not allow users to attempt to converge on real starting materials, or to pinpoint the shortest possible routes. Finally, the system's concentration on the functional groups in the desired compounds involves a subtle deception. Many good syntheses use particular functional groups for key construction steps en route but eliminate them later. Hence, those groups do not appear in the target molecule as guides for retrospective analysis of the synthesis. That fact underscores the contention that good chemists use more subtle, less mechanical thought processes in intuitively constructing short, elegant syntheses than such a stepwise computer program can possibly manage.

### Synthesis by Logic

At Brandeis, we have developed a logic-oriented approach to synthesis that avoids some of the shortcomings inherent in information-oriented systems. Called SYNGEN (for synthesis generation), the program uses no library. Instead, it generates each reaction from reaction-mechanism theory. This is made possible by reducing pictorial molecules to strings of numbers suitable for computer manipulation. The numbers represent the types of bonds linking carbon atoms in the skeleton and the functional groups, and the positions in which the bonds appear on the skeleton. The computer generates all possible reactions by adding to an individual molecule's number strings of other numbers corresponding to changes that a reaction causes. This enables the chemist to derive the number strings for the starting molecules in the synthesis.

This system has advantages beyond the fact that it doesn't need its own library of reactions. The economy of the approach reduces storage space and computer time, and allows all combinations to be examined. It also enables the program to consider the best ways to dissect the carbon skeleton before dealing with the details of the functional groups.

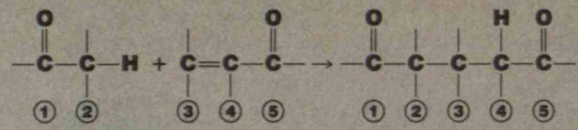
The latter point is important because synthesis fundamentally stems from the concept of the carbon skeleton. The simplest gross description of any synthesis identifies which new skeletal bonds are formed by linking together simple starting skeletons, and the order in which the bonds are formed. The system basically asks how many ways a carbon skeleton can be dissected into smaller pieces, and then uses programmed criteria to select the most promising ways to reverse the process and thus build up the target molecule.

That process may appear easy, but it involves extraordinary numbers. At Wyeth Laboratories, chemists begin synthesizing the sex hormone estrone with four starting materials and create 5 new bonds out of the total of 21 on the carbon skeleton of estrone. It turns out that 2.5 million different ways exist to achieve that dissection even without considering the necessary chemical reactions! Plainly, we must apply stringent criteria to select the best synthesis routes.

Our basic criterion for SYNGEN is that of economy. Because of the uncertainties involved, our program does not predict the yields of reactions. Hence, we must minimize the number of steps: the fewer the reactions that must be executed, the more economical the synthesis. The program first seeks ways to cut the skeleton of the target compound into the largest and fewest starting skeletons—and hence the fewest number of bonds to assemble by construction reactions. This allows the search to focus on real, available starting materials. Only when those are identified does the program concern itself with which functional groups to add to the skeletons to make the reactions go. The program then minimizes steps by allowing only construction reactions to be used. This procedure reduces the number of optimal syntheses to a tiny proportion of the number possible—perhaps as few as 20. And it has a major advantage not found in information-oriented programs: the program will often "invent" new chemical reactions that, while not in any chemical library, might be coaxed into action in the laboratory.

The SYNGEN program focuses primarily on complex molecules typical of medicine, and accepts as starting materials the many products of the chemical industry. Those products themselves stem from a network of large-scale industrial synthesis that relies on a small number of primary chemicals. Not surprisingly, some chemical engineers have started to develop logic-oriented programs to seek simpler, cheaper routes to synthesizing these products. The REACT program of Gary Powers and Rakesh Govind at Carnegie-Mellon University is typical. While its

The logic-oriented approach to chemical synthesis, typified by the SYNGEN program, uses strings of numbers to represent compounds. The strings indicate the number of bonds linking each carbon atom to atoms other than carbon and hydrogen (Z), and the number of multiple bonds to adjacent carbon atoms ($\pi$).
Similar number strings represent changes in the values of Z and $\pi$ caused by specific reactions. By adding the number strings for a molecule and a specific reaction, the SYNGEN system yields the expected products of that reaction. By reversing the process, the program determines the possible starting products for any particular synthesis.



Z$\pi$ = 20 00 + 01 01 20 → 20 00·00 00 20

**Reaction generator**

②·③ ④
Δ Z$\pi$ = 00 -01 -01

**OR:**

| | | | |
|---|---|---|---|
| **STARTING:** | 20 00 +01 01 20 | **PRODUCT:** | 20 00 · 00 00 20 |
| **+ΔZ$\pi$:** | 00 -01 -01 | **−ΔZ$\pi$:** | 00 +01 +01 |
| **PRODUCT:** | 20 00 · 00 00 20 | **STARTING:** | 20 00 +01 01 20 |

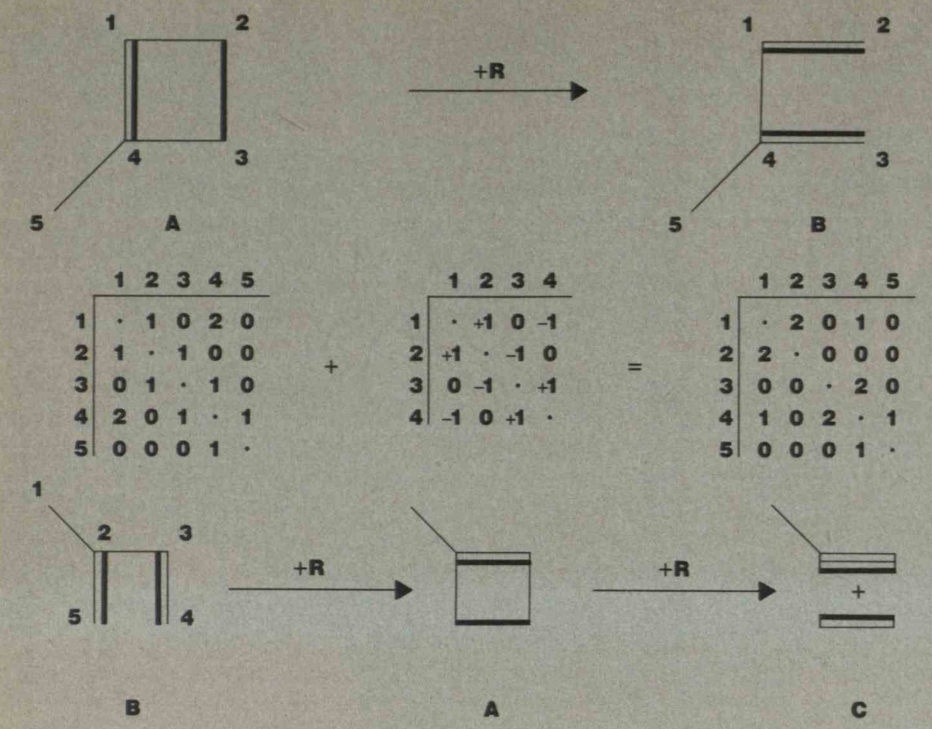
target molecules are simpler than SYNGEN's, the program must further take into account the costs of starting materials, chemical processing, and energy, as well as the toxicity of by-products. Complicating the problem further is the fact that much of the basic information necessary to feed this type of program is proprietary.

The other logic-oriented approach, based on mathematics rather than chemistry, is being developed by Ivar Ugi and Johann Gasteiger at Munich's Technical University. Called EROS, the program represents the most fundamental approach to synthesis. It seeks simply to identify all possible ways of shifting about the bonds that link atoms in any molecule or group of molecules. Not only does EROS require no library of chemical reactions; because it is numerical, it is also entirely free of the constraints of reaction mechanisms.

The method resembles SYNGEN in that it represents molecules and types of reactions in codified form. But instead of simple strings of numbers, the representations are in the form of matrices—that is, groups of numbers organized into rows and columns. Any group of molecules can be organized into a matrix in which each single atom has its own row and column. The numerical entries in the matrix represent the number of chemical bonds that link the atom to adjacent ones. Chemical reactions are represented by matrices with + (add bonds) and − (break bonds) numbers. The reaction matrices are added to product matrices to derive the starting molecule matrices for the reaction, like the process of adding number strings in SYNGEN.

Working backward from the target, chemists must first include in its matrix a set of small molecules, such as water, that might be by-products of a reaction. Then, reaction matrices are systematically added in all possible ways to generate a series of intermediate molecules. In due course, the additions will create a family of acceptable starting materials for the synthesis. In effect, the system has mathematically mimicked the reaction sequences of a synthesis—in reverse, of course.

As with other computerized methods, the key to the EROS program is selecting the best route from a huge number of possibilities. EROS has thus been able to reproduce the SOHIO process—named for Standard Oil of Ohio—that converts simple substances into acrylonitrile, which is then polymerized into fibers. This process involves 32 atoms requiring 512 separate spots in the matrix. Since 30 chemical bonds link the atoms, the number of possible combinations is 512 items taken 30 at a time—an almost infinite number of possible routes. Plainly a rigid form of selection is vital. EROS makes this selection by calculating the energies of new bonds created by each possible reaction, in order to judge whether the molecules produced by the reactions are really stable. A testament to the success of this method is the fact that, of all computer programs, only EROS predicts the reactions of the SOHIO process, achieving what normal mechanism theory cannot.




**The EROS program approaches synthesis from the most fundamental point of view—that of basic mathematics. Groups of molecules are arranged in mathematical matrices. These rows and columns of numbers represent the number of chemical bonds that link atoms to their neighbors.**

**Matrices can also be used to represent reactions. Positive numbers reveal that the reaction creates new chemical bonds, while negative numbers indicate that the reaction breaks existing bonds. By adding a reaction matrix to the matrix that corresponds to the desired products of any synthesis, the program derives the matrices of the possible starting materials for that synthesis.**

Because EROS represents the most fundamental of all approaches to computerized synthesis, it is also the hardest to develop to a practical level. Calculating the energies of bonds is itself a complex problem. In principle, the program can find every conceivable reaction route. But since the number of possibilities is so immense, sorting the good from the bad is very difficult—much more than in the other approaches.

## Will Chemists Accept Computers?

Few chemists have worked to develop computerized synthesis, as most regard the design of synthetic routes to new compounds as the major intellectual challenge of their profession. By taking over that process, many scientists believe, computers will reduce chemists to the level of intermediaries who oversee technicians carrying out syntheses suggested by the system. It's not surprising that chemists have resisted a systematic, mechanical approach to synthesis that threatens to displace their personal creativity, much as composers might resist computerized composition of symphonies.

Chemists have further reason for suspicion. No computer has yet projected an entirely new synthesis that has actually worked. And chemists using information-oriented programs realize that they are relying on the judgment of other chemists to set up the databases. Thus, good chemists have no confidence that the reactions the computer rejects would not work.

Overall, industrial chemists have watched skeptically from the sidelines as a few research teams have developed computerized systems for synthesis. Most chemists are waiting for proof that the schemes are sound enough to justify investing in a large computer and the intense, expert labor required to build an adequate database. Logic-oriented programs, which do not need databases, have only recently become ready for practical use and have not yet been broadly tested.

In the long term, logic-oriented programs, which can introduce unknown reactions, will probably broaden the scope of chemical synthesis more than information-oriented programs. But the possible reaction sequences generated by both types are still too numerous for practical use. Researchers have not yet clearly defined a firm basis for telling computers how to select the best sequences. If the basis is skewed in some way, the system will miss many good sequences; if it is too permissive, the system will create too many options. What is essential is that the wisdom of sophisticated organic chemists be incorporated into these programs. We must hope that this will happen, if only slowly, as the programs are more widely used and chemists soften their resistance and start helping to develop these aids.

*JAMES B. HENDRICKSON is professor of organic chemistry at Brandeis University. He has worked on the theory and practice of computerized chemical synthesis since 1970.*

DIAGRAMS: OMNIGRAPHICS

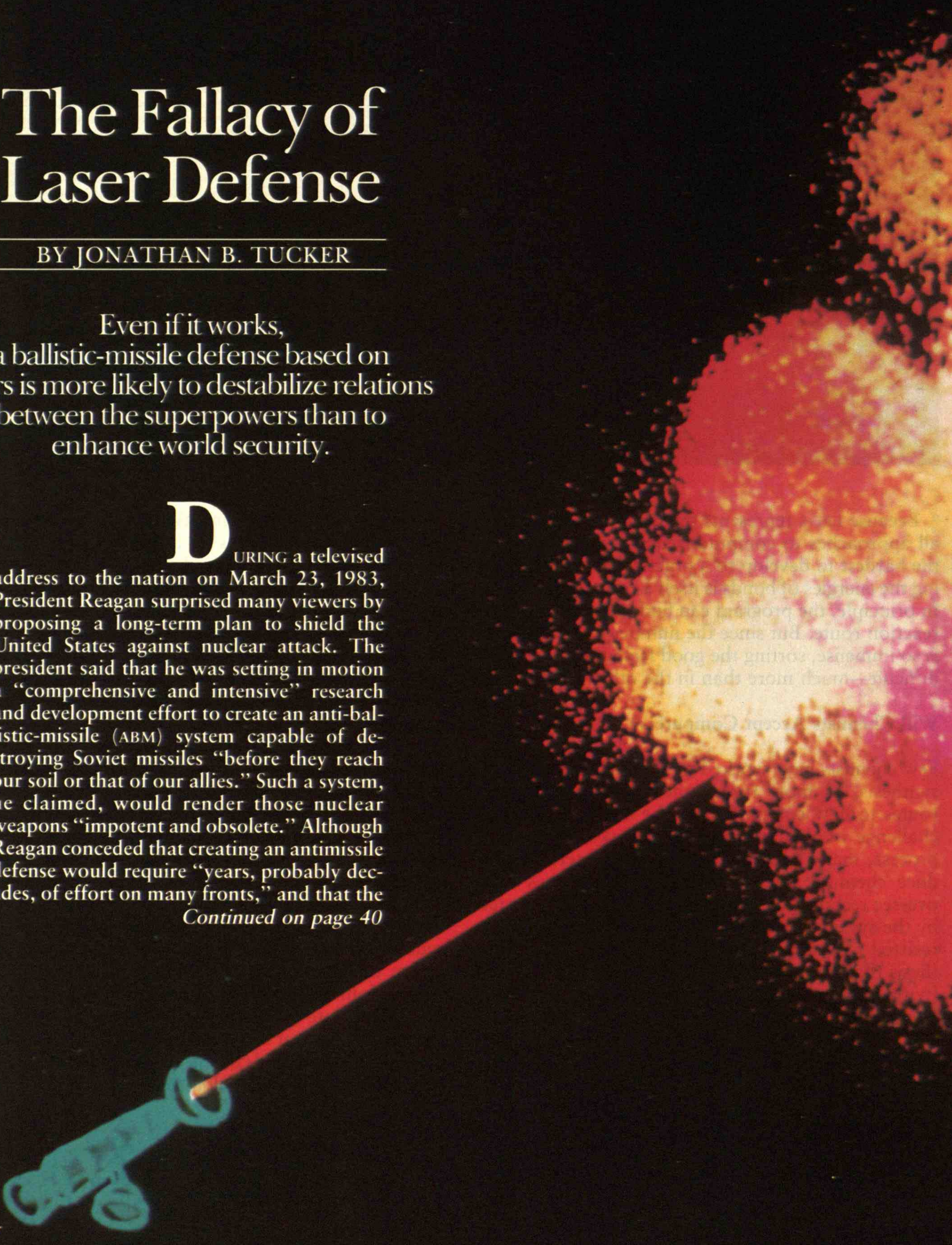
# The Fallacy of Laser Defense

BY JONATHAN B. TUCKER

Even if it works, a ballistic-missile defense based on lasers is more likely to destabilize relations between the superpowers than to enhance world security.

DURING a televised address to the nation on March 23, 1983, President Reagan surprised many viewers by proposing a long-term plan to shield the United States against nuclear attack. The president said that he was setting in motion a "comprehensive and intensive" research and development effort to create an anti-ballistic-missile (ABM) system capable of destroying Soviet missiles "before they reach our soil or that of our allies." Such a system, he claimed, would render those nuclear weapons "impotent and obsolete." Although Reagan conceded that creating an antimissile defense would require "years, probably decades, of effort on many fronts," and that the

*Continued on page 40*



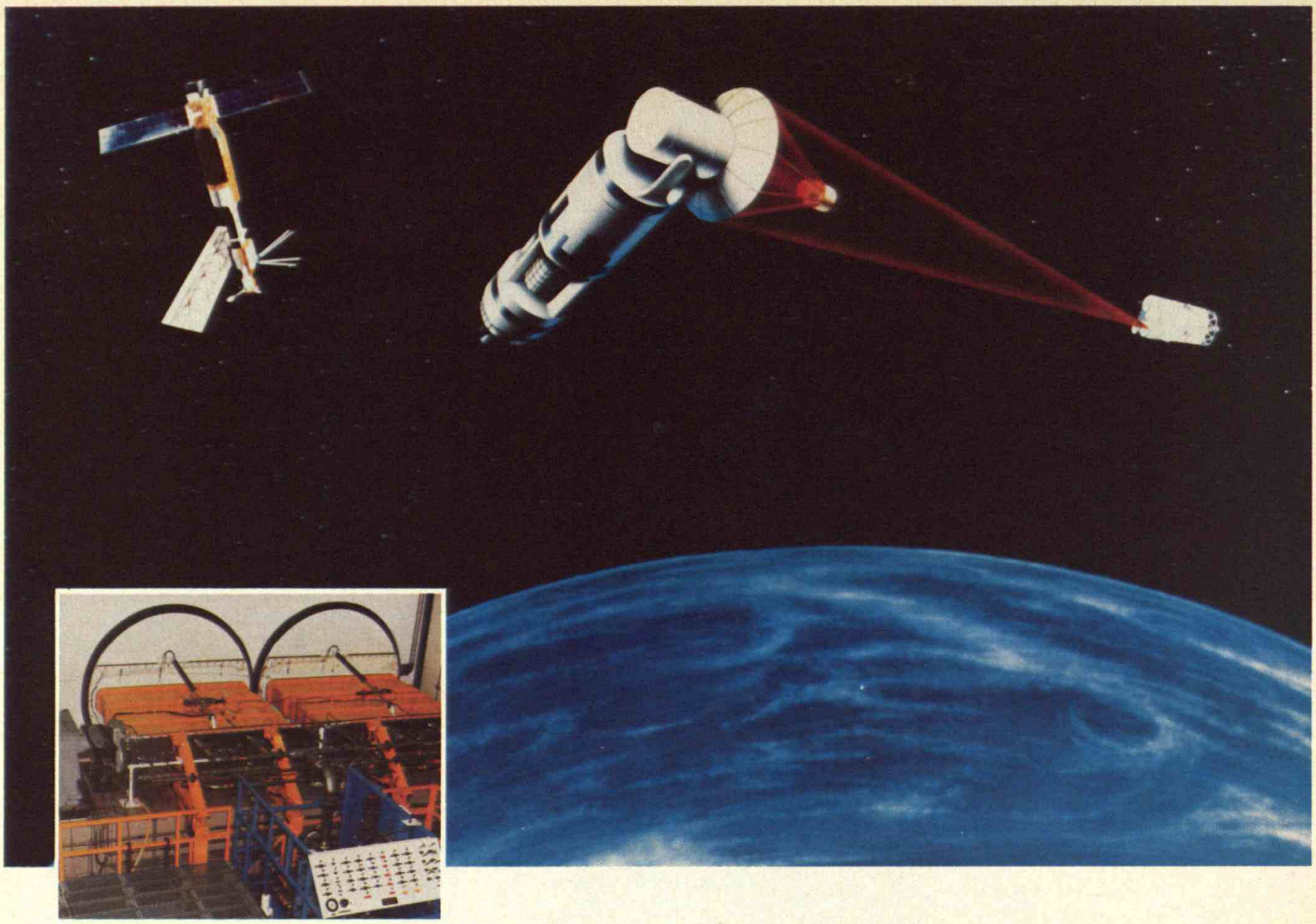
# Fighting MAD

BY CAROLYN MEINEL

New offensive nuclear weapons are making war more likely. A defense against missiles could counter that threat and help reduce nuclear stockpiles.

ONE year ago, President Reagan called upon the scientific community to devise "the means of rendering these nuclear weapons impotent and obsolete." Though the opposition was quick to react, and much of the press satirized the proposal as a "Star Wars" fantasy, the White House received some 2,500 phone calls running ten to one in favor. It was the most enthusiastic response to any speech Reagan had ever given. Even the Pentagon was deluged with fan mail. *Continued on page 32*

ILLUSTRATION: TOM NORTON



Within the defense establishment, the president's speech encouraged the growing network of those studying weapons that truly could be defensive. Unlike nuclear missiles that could kill masses of people, these weapons—possibly based on lasers, beams of subatomic particles, or even metal projectiles or conventional explosives—would shoot down missiles only after they were launched, and would be unlikely to kill people. A Defensive Technologies Study Team was set up under the leadership of former NASA director James Fletcher in the Office of Defense Research and Engineering. Fletcher's people were good sports about the Star Wars sniggers of the media, plastering *Return of the Jedi* posters throughout their headquarters in Arlington, Va. But the team was altogether serious about seeking a defense against ballistic missiles.

This is truly a revolution in thought about nuclear defense, and I would like to discuss it from a somewhat personal perspective. I started out on the other side of the fence, persuaded that schemes to provide a ballistic-missile defense—BMD, as it has come to be called—would be ineffective and likely to touch off the very war they sought to prevent. But my view has changed.

In 1976 I collaborated with Norrie Huddle, an environmentalist who later became codirector of the antinuclear Mobilization for Survival, on a presentation about BMD to the United Nations Habitats Conference in Vancouver, Canada. Working under the auspices of the L-5 Society, a space lobbying group I headed, we put forward most of the arguments against BMD that are heard today. Could a nation use BMD to shield itself while devastating another nation with a first strike? Would the prospect of one nation's developing an effective defense against nuclear missiles tempt the other nation to launch its missiles before that defense was in place? If defenses turned out to be terribly expensive, might opposing nations find it easiest to counter them by a buildup of yet more nuclear weapons? Our fears merely drew yawns from the audience: in 1976 most people assumed these scenarios were safely in the future.

As the L-5 Society's budget moved into the six figures, and as I began writing regularly for science magazines, two of the prime activists in the pro-BMD movement targeted me for persuasion. Lockheed's Max Hunter, originator of the concept of the space-based laser, buttonholed me first. On a sultry June afternoon in 1978, after we had both given briefings on space solar power to officials in the Department of Energy, Hunter pressed on me a copy of his pamphlet, "Strategic Dynamics and Space Laser Weapons." I didn't like his idea of a laser-enforced Pax Americana (Hunter's own term). My gut instinct was



ILLUSTRATIONS: DEPARTMENT OF DEFENSE

**This space-based laser weapon has been envisioned by the High Energy Laser Program of the Department of Defense. Inset: The Mid Infra-Red Advanced Chemical Laser is being developed at the White Sands Missile Range in New Mexico for tests to be run in the mid-1980s.**

against trying to corner a nation armed with doomsday weapons. However, I could also see that if our intelligence estimates about Soviet directed-energy weapons were correct, we might get backed into that very corner.

I was disarmed by Hunter's relaxed, optimistic viewpoint. I was surprised to learn that he regarded the vested interests behind U.S. nuclear weapons to be his most dangerous opponents. "This is going to be built on a pile of broken rice bowls," Hunter chuckled as he predicted the uproar that would occur once defense contractors realized that he was talking about terminating many billions of dollars worth of nuclear-weapons programs. In spite of myself I became tempted by his vision of putting the MX and other weapons of mass destruction out of business.

In 1978 another leading space-defense activist visited me in Tucson. John Rather had worked there as a radio astronomer at Kitt Peak in the early seventies, and he had led an effort to ban the use of the police helicopter, so I knew he was no knee-jerk militarist. I was fascinated by his vision of a future in which nuclear weapons will have fallen before BMD, possibly as dramatically as that medieval offensive weapon, the knight in shining armor, did to improved long-bow technology.

The knights of the medieval era, carrying plate armor and an impressive arsenal of weapons astride a ton of horse, had seemed unstoppable. But some British military innovators became convinced that hard yew wood imported from Italy and Spain, fashioned into a six-foot long bow and handled by a common yeoman, could fire arrows with such force as to render these knights "impotent and obsolete," to borrow Reagan's words.

The first test of this new technology was in the battle of Crecy on August 26, 1346. Some 20,000 British soldiers, primarily bowmen, tackled 60,000 French warriors, including 12,000 armored knights and 17,000 less heavily armored cavalrymen. The English suffered fewer than 200 dead and wounded. The French lost 1,542 knights and lords and some 15,000 other men. After this debacle the knight in shining armor faded into legend. Until another offensive weapon was developed—a cannon effective enough to batter down walls—people who lived in fortified cities were relatively safe.

I was impressed with Rather's ability to use historical analogy to illustrate how technological change has sometimes decreased the horror of war—and may, if properly harnessed, do so again. So I arranged through a grant from the National Endowment for the Humanities to bring Rather back to Tucson to debate three opponents of BMD. One of them, Ardner Cheshire, an English professor at the University of Arizona with a special interest in technological issues, was so charmed in predebate discussions with Rather that he opened the debate by admitting that he had been won over.

By late 1979 Hunter and Rather were winning major support for their approach in Congress: Sen. Malcolm Wallop (R-Wyo) and Rep. Ken Kramer (R-Colo) emerged as leading advocates of what Kramer calls "homeland defense." Both Hunter and Rather came under pressure to tone down their advocacy from a defense establishment that favored the MX missile, but the revolution in defense thought had become too big to bottle up. Edward Teller, who had conceived the H-bomb, became captivated by the promise of "third-generation" nuclear weapons—devices that would use small nuclear explosions to destroy missiles but not large numbers of people. When the results of a test of Teller's x-ray laser were leaked, he found himself center stage. President Reagan asked him to evaluate the promise of BMD, and many believe Teller was the person most responsible for the Star Wars speech.

Why did I abandon my qualms about defensive systems? To illustrate, let me describe the gist of a conversation I had recently with John Gardner, who handles defensive systems in the Office of Research and Engineering at the Pentagon, and John Pike, a leading opponent of BMD. Pike is an analyst with the Federation of American Scientists and, like me, an old L-5 Society activist.

We rehashed the familiar issues: Can BMD really work? Would it bust the budget? Could one nation use BMD to blind another's surveillance satellites and cut communications, tempting the blinded nation to push the button? Could one nation disable the other's space-based defenses before moving in with a nuclear strike?

I will explain our specific arguments shortly. But Gardner summed up the discussion with a simple statement: "There is something intuitive about defending yourself."

This is the concept supporters of a missile defense start with. Despite the complex arguments supporting today's strategies behind offensive weapons and mass retaliation, we feel a simplicity and moral force

behind our dream. Through science and technology we seek devices that could ensure our nation's security without threatening to devastate our planet. Yes, we seek a technological fix—just like the medical advances that have eradicated deadly communicable diseases.

### The Crumbling Rationale of MAD

Defense Secretary Robert MacNamara settled on the strategy of mutual assured destruction (MAD) in the sixties. The reasoning went this way: Suppose a nation suffered a nuclear attack. As long as enough of that nation's nuclear weapons survived, it would still be able to destroy its opponents' cities. Thus, no one would be the first to push the button. Winston Churchill summed up this strategy: "Safety will be the sturdy child of terror, and survival the twin brother of annihilation." But technological advances are fast altering the calculus of MAD.

One of these advances—improved guidance systems for missiles—seemed a pure blessing for many years. It helped to decrease the megatonnage of the U.S. arsenal by over 60 percent in the last two decades. If a weapon can be delivered within only miles of its target, a multimegaton warhead is needed, but if the weapon can be delivered closer, less explosive power can do the job. In fact, some weapons planners hope that nuclear warheads may eventually be replaced by conventional warheads that will rely on great accuracy to destroy their targets. One such weapon emerging from the laboratory is Axe, which would be delivered by a Trident II missile launched from the ground and used to destroy airfields. Another is Assault Breaker, a system of missiles employing conventional explosives that would replace tactical nuclear weapons in Europe designed to destroy invading tanks.

However, a second technological development—putting multiple warheads on missiles—can have a disastrous effect when those missiles are highly accurate. Both our MX (not yet deployed) and the Soviet SS-18 (already deployed) are allowed under the terms of SALT II to have 10 "multiple independently targeted reentry vehicles" (MIRVs), each of which can drop one bomb very precisely on a target. Either an MX or an SS-18 could destroy several of the opponent's missiles in their silos. Thus, whoever strikes first could wipe out most of the other side's ground-based intercontinental ballistic missiles (ICBMs).

Backers of MAD point out that land-based ICBMs are only one leg of the U.S. and Soviet "triad" of forces. Even if land-based ICBMs are vulnerable to a first strike, we still have air- and sea-launched cruise missiles and submarine-launched ICBMs. However, these two legs of the triad are subject to antisubmarine warfare and antiaircraft defenses. Also, submarine-launched ICBMs are highly inaccurate. This means that they must carry huge warheads to retaliate against military targets. If those warheads were used, global contamination by radiation would result, and possibly the "nuclear winter" of which Carl Sagan and other scientists warn.

Proponents of MAD may argue that such unthinkable damage is a salutary threat. Without it, some nation might think it could win a nuclear war. But for all its horror, the threat might not work. Consider a scenario that analysts have suggested: Using accurate, small nuclear weapons, the Soviets launch a "surgical" strike against our ICBM fields, ports serving nuclear submarines, and airfields for planes that launch cruise missiles. Many people would die—perhaps millions—but the dust clouds and radiation wouldn't be enough to harm seriously those living far from military bases. Would we hold our fire, preferring to negotiate and rebuild? Or would we sign the death warrant for our planet? No one wants to find out. Such nuclear "warfighting" scenarios were discussed frequently in the Carter administration and have also been turning up in Soviet literature. Many of us fear that they herald the breakdown of MAD.

It could be argued that cruise missiles could retaliate in a measured way even after a surgical first strike on military targets; hence they preserve the balance of MAD. Cruise missiles probably could survive a first strike because they are so small that they can be well hidden. By recognizing the contours of the terrain they fly over, they can deliver small warheads accurately, and thus could be used to retaliate against military targets without destroying an entire nation.

Midgetman, the proposed small, portable ICBM with a single warhead, would also shore up MAD. For example, in a first strike the Soviets might destroy 100 large MX missiles (carrying 1,000 warheads) but would have a harder time destroying 1,000 small Midgetmen (also carrying 1,000 warheads). In addition, Midgetman would be easier to hide and therefore harder to target than the MX.

However, the very qualities that make the Midgetman and cruise missiles capable of surviving a first strike and retaliating in a measured way also pose problems for verifying arms agreements. Weapons that can be concealed in wartime can also be concealed in peacetime, making it hard to verify whether any nation is adhering to a treaty. To the Soviets, every airplane may begin to look like a cruise-missile launcher, and a Midgetman could even be hidden in a semitrailer. U.S. military planners will be similarly skeptical regarding comparable weapons deployed by the Soviets.

Even now, the Reagan administration and others fear that the Soviets are breaking treaties. With the advent of easily hidden weapons, these fears could only grow. It doesn't take much imagination to predict the outcome. An incident from the sixties furnishes an example: the United States built up its ICBMs to close the "missile gap" projected by intelligence agencies, but after reconnaisance improved, it turned out that the gap had not existed. The buildup had been fueled only by fear.

Many of us have come to believe that no matter how good a given arms-control agreement, and no matter how much the Cold War may thaw, MAD possesses an inherent ratchet effect. Our only arms reduction occurred in the sixties—after our surveillance satellites had showed that our destructive power was way beyond that of the Soviets. Once we dropped to near parity, however, our trend has been to keep pace with the Soviet buildup. For their part, the Soviets are trying to match *all* their opponents' arms. The British are scaling up from some 300 warheads to 1,900 by the early nineties, while the French have comparable plans. And the Soviets fear U.S. Pershing missiles, which use radar to sense the terrain and achieve phenomenal accuracy. No wonder SALT doesn't seem to work!

**Asteroids might prove to be a cheap source of stainless steel, which could be used to provide armor against lasers in space. The armour could protect surveillance and communications satellites as well as laser weapons, so they would be available to shoot down offensive nuclear missiles.**

The final factor eroding MAD is the proliferation of both nuclear weapons and the missiles that can unleash instant war. India and China possess impressive and growing rocket and nuclear technologies, and Third World nations from Pakistan to Libya are avidly pursuing these technologies. Can MAD continue to work as both the number of nuclear powers and the legions of warheads proliferate? The spectre of accidental war, caused by misunderstanding between the superpowers or escalation of a backwoods conflict, makes Churchill's vision of a nuclear - weapons - enforced peace increasingly naive.

But if we can devise purely defensive systems—to destroy weapons, not planets—then we can increase these defenses rather than rattle nuclear sabres if arms control fails. As President Reagan put it in his March 1983 broadcast, "Is it not better to save lives than to avenge them?"

## Getting Away from MAD

A major question in shifting from weapons of retaliation to weapons of defense is how to get from here to there without passing through Armageddon. If one side starts to install a nuclear defense, the other side might feel threatened to launch its missiles before they become useless.

Gen. Daniel O. Graham, retired head of the Defense Intelligence Agency, argues that simply announcing our intention to develop defenses will enable us to start dismantling the machinery of MAD. Graham, who has organized tens of thousands of backers behind his High Frontier BMD lobby, points to NATO's experience in the early fifties. Western

European nations argued that if they were to avoid Finlandization—intimidation by the Soviets—the United States would have to help them match Warsaw Pact forces soldier for soldier and tank for tank. But instead of embarking on a massive buildup, we promised our allies tactical nuclear weapons. Not that we knew then how to fit a nuclear warhead inside an eight-inch artillery shell, for example; all we had were multiton behemoths. But the promise that the United States was working on these devices to counter the Warsaw Pact advantage in ground forces was enough to cement the NATO alliance.

Can this experience suggest how to deploy BMD—without triggering war through the threat implied by BMD when combined with offensive weapons? As the NATO experience showed, developing tactical nuclear weapons was an effective substitute for a huge conventional arms buildup. However, if such a buildup had been carried out in addition to deploying tactical nuclear weapons, the combination could have seriously provoked the Warsaw Pact. Could a new Western focus on defensive weapons—*instead* of offensive weapons—safely pave the way from MAD to mutually assured safety?

Again, the NATO nations seem to be buying the idea. The NATO parliamentarians meeting, composed of delegates from the U.S. Congress and parliaments of other members, convened last October to consider, among other issues, Reagan's Star Wars proposal. The staff of the Science and Technology Committee had prepared a report decrying BMD, but the meeting finally voted 199 to 1 in favor of it. Thomas Lefebre, the Canadian Liberal who drafted both the initial report skeptical of BMD and the final pro-BMD resolution, asserts, "The attacker could never be sure which of his warheads would get through. This uncertainty would make a comprehensive first strike almost impossible and therefore unlikely." Western European nations may be hoping to escape their long reliance on nuclear retaliation through BMD plus highly precise conventional weapons such as Assault Breaker and Axe.

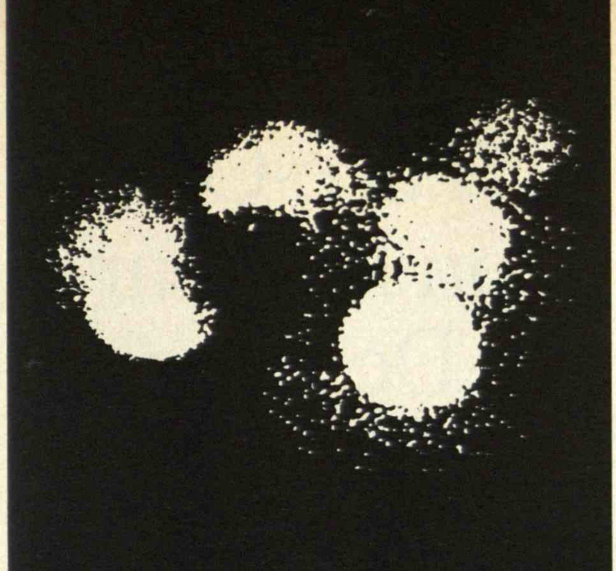
Europeans learned once before that defense can work. In the late twenties and early thirties, British strategists thought that bombers, especially if equipped with biological or chemical weapons, could wipe out entire nations in a matter of days. "The bomber will always get through," asserted British Prime Minister Stanley Baldwin in 1935. In that same year Winston Churchill appealed to the House of Commons for air defenses: "My experience is [that] when the need is fully explained by military and political authorities, science is always able to provide something." As history shows, no nation did escalate to biological or chemical bombs, and scientists did develop an impressive array of antiaircraft technologies—radar, flak, and fighters. Thanks to the bombers' difficulties in getting past air defenses, the average bomb fell some five miles from its intended target.

Of course, the flip side of this defensive strategy is that World War II did start. Opponents of BMD fear a repeat of this part of the story. Ballistic-missile defenses might make world leaders more willing to hazard war, and even if only a few nuclear warheads leaked through, millions could die. As the old saying goes, if it works, don't fix it—and whatever the flaws of MAD, we have avoided major war since 1945. However, those of us who back research into defensive weapons point to another saying: Murphy's Law. If anything can go wrong, it will—sooner or later.

**Will BMD Work?**

Most of those who argue against BMD say it just can't be done. John Pike and I have spent more than one evening positing measures and countermeasures and countercountermeasures. I put up a free-electron laser to zap missiles. He says he'll launch his SS-18 with five warheads instead of ten, using the extra throw-weight to shield it against my laser. I say I'll give my laser more energy. He says he'll use a laser of his own to burn down my laser before launching his SS-18 barrage. I say I'll put armor on my laser and throw up cheap decoys to confuse his laser. Pike argues that for 15 percent of the cost of SS-18s he can launch dumb decoy missiles that will fool my laser into wasting energy on them. On and on the arguments go.

They can be answered by pointing to possible technological developments, and they can also be answered in a broader way. First, consider one technology that I am working on as an example of possibilities to come. The idea arose at a Christmas party I held in 1982. One of the guests was John Lewis, a scientist who contributed to the evidence that an asteroid striking the Earth caused the Cretaceous extinction, killing most life in the ocean.



*Technological advance is not random: we can focus on systems to defend ourselves without harming people.*

Brainstorming about whether defensive weapons could be capable of surviving attack, Lewis, myself, and others had an idea. Stainless steel occurs in near-Earth asteroids, and because it is already in space, it could be used to build inexpensive armor for defensive satellites. Cost is critical here. Defensive weapons must be relatively cheap, or the opponent will overwhelm them by adding ICBMS.

Last August Lewis and I met with James Fletcher, head of Reagan's Defensive Technologies Study Team, to detail our research. The Fletcher report has not yet been made public, but it appears that it will call for some research on our idea.

Even some opponents of BMD, such as Pike, are excited by the potential of asteroid resources to protect surveillance and communications satellites. Pike recently visited the Soviet Union for a conference on the threat Soviet scientists see in Reagan's Star Wars initiative, and he learned that they, too, are interested in asteroid mining. In fact, Georgi Manigadze, Pike's Soviet host, asked him and other representatives of the Federation of American Scientists to inquire informally whether the United States and the Soviet Union could cooperate in asteroid ventures.

But my optimism about the possibilities of BMD does not rest on this or any other specific technology. I am a technological optimist. I would hate to be the latest in that long series of eminently qualified people who have said that everything from the wheel to spacecraft was poppycock.

Much as BMD technology is sometimes ridiculed today, the basic weapons of today's MAD were once ridiculed. President Harry Truman recollected when Admiral William Leahy advised him on the nuclear bomb. "That is the biggest fool thing we have ever done," Leahy said. "The bomb will never go off, and I speak as an expert in explosives." Later that year, after it had become all too apparent that the atomic bomb was not science fiction, another Truman advisor hazarded an opinion on a related subject. "I don't think anyone in the world knows how" to build an ICBM, Vannevar Bush proclaimed. "I feel confident it will not be done for a very long time to come." Knowledgeable people can be very wrong.

But oddly enough, the point made by Bush and Leahy—that making nuclear bombs and ICBMS work is extremely tricky—suggests to me that they may be vulnerable to defensive technologies. To be sure, a college student can learn the theory of building an atomic bomb after browsing through the open literature. However, as a number of ambitious but technologically backward nations have learned, translating theory into technical precision is the tough part. The pieces of U-235 or plutonium in a bomb must be shaped exactly right. A powerful explosive must bring them together into a perfect sphere of critical mass with precise timing. Even slight damage to such a bomb can turn it from a device of terror into a collection of radioactive pieces of junk.

The delivery systems are vulnerable, too. In World War II, the B-17 bomber was famous for being able to fly even though shot full of holes. Yet that era's air defenses kept it from becoming an unstoppable weapon of terror. Today cruise missiles are designed to evade air defenses by being so small that they can hardly be spotted by radar. But the cruise missile's very compactness means that one hole in it anywhere will destroy something vital. Rockets, too, are vulnerable. If only slightly damaged during the boost phase, they explode or veer off course.

I'm not prepared to bet that if we held World War III, no warhead would get to its target. However, I believe that warheads may be vulnerable to a gamut of defensive systems. Of course, BMD offers no defense against terrorists who might deliver atomic bombs in suitcases, but MAD doesn't either. And if defensive technologies help us to shrink or even eliminate nuclear stockpiles, they may reduce the likelihood of a black market in nuclear warheads.

Thus, siding with Churchill's sentiment of 1935, I believe in defense, and I believe that science can help us achieve it. Technological advance is not ran-

*Continued on page 50*

# Face-Off on Nuclear Defense

*Two prominent scientists who worked on the Manhattan project to develop the atomic bomb during World War II disagree about whether the United States should try to build a defense against nuclear missiles. Edward Teller, senior research fellow at the Hoover Institution at Stanford University, was largely responsible for devising the hydrogen bomb. He is often credited with advising President Reagan about the potential for a ballistic-missile defense. Hans Bethe, professor of physics at Cornell University, was head of the theoretical division at Los Alamos National Laboratory during World War II, when the first nuclear weapon was developed. He won a Nobel Prize for his work in describing the fusion reactions that fuel the sun and stars. He believes that the idea of a ballistic-missile defense for the population remains in the realm of science fiction.*

*Teller and Bethe discussed the Reagan proposal last November at the Kennedy School of Government at Harvard. Excerpts of their debate follow.*

**TELLER:** There cannot be the slightest question that our purpose is to prevent nuclear war. The question is, how? I believe that mutual assured destruction, a policy that attempts to prevent war through the threat of retaliation, is not only repulsive; it is unacceptable to the people of the United States. I believe that effective defense is possible. It must be less expensive than offensive measures the opponent might take to overcome it. If this is the case, both sides will automatically be forced into defensive postures.

In the 1950s I did not think a defense against ballistic nuclear missiles was possible. But by 1969 I thought there was a real chance, and I want to tell a story about a talk I was invited to give at that time in Glacier National Park. A speaker introduced me: "Here is Dr. Teller. He went for a walk this morning, and some of us went with him. A couple of hundred yards from the lodge, he picked up a big stick. I asked, 'Dr. Teller, what's that stick for?' Dr. Teller said, 'It is to use against grizzly bears.' I said, 'Dr. Teller, don't you know that a stick can't protect you against grizzly bears?' Dr. Teller said, 'Yes I know, but I hope the grizzly bears don't.' "

I deserved the criticism. At the time I did not know that we had good enough sticks. But I did know then that the grizzly bears in the Kremlin are exceedingly cautious. If they are not sure, if they cannot calculate that they can win, then they won't start.

*Bethe: "Embarking on a space defense will nullify any attempts at arms control for 20 years."*

Since that time, a number of ingenious ideas for ballistic-missile defense have been put forward. X-ray lasers and common lasers can be used, but for security reasons I am not allowed to detail how.

Of course, people ask if such a defense can be 99 percent efficient. Let's make it as efficient as we can, but if it is 80 percent efficient on paper, we have got something. That means that in reality it is 50 percent efficient—or perhaps even 95 percent efficient—and because those grizzly bears are cautious, they will have to assume that it is 95 percent efficient. If we haven't done anything else, we have raised uncertainty and gained time for cooperation.

This brings me to a few general words about offense and defense. Offense has the advantage of surprise. But in the past attackers had to walk a long way and got tired by the time they got to the battle. The attackers have to shoot faster and bear greater expenses than those who merely want to defend. The defenders need not expend as much money or effort, but they must have one thing: ingenuity. Complete safety requires infinite ingenuity. This does not exist, and therefore no defense will be perfect. But it can be very good. If enough of our first-class scientists help, there is a chance of enough ingenuity to prevent war.

I believe we have a moral and practical obligation to develop defense. The Soviets are already developing civil defense. They have a good ballistic-missile defense around Moscow and have been greatly improving it. We cannot afford *not* to defend ourselves. To promise peace today is impossible, but to find approaches to defense that may lead toward peace—that I think is posssible.

**BETHE:** I do not believe that President Reagan's "Star Wars" proposal, as it is generally known, can work. In his speech announcing the idea of ballistic-missile defense, Reagan said, "I clearly recognize that defensive systems, if combined with offensive systems, can be viewed as fostering an aggressive policy, and no one wants that." But no matter what the intentions of the U.S. government, the Soviets would almost surely consider a ballistic-missile defense to be an aggressive policy. They would therefore take opposing action. The sophistication required to build a space-based defense is so great that I doubt even the United States will be able to accomplish it. Because the Soviets are appreciably behind in high technology, they are not likely to choose this direction. Instead, they will opt for the simplest course—building more missiles. Undoubtedly, we will follow and increase our missiles, intensifying the arms race.

All the proposed schemes for space-based defense pose huge problems. There are three places where an enemy missile can be attacked. The boost phase has advantages because while a missile is being boosted, it emits a flame that can be aimed at. Also, the defense has to attack only a single object—the booster missile—and that booster is more vulnerable than the reentry vehicles carrying individual warheads that come out of it.

But the boost phase lasts a very short

time—something like two to five minutes. In fact, most proposed methods to destroy the booster must operate outside the atmosphere, and the time the missile spends outside the atmosphere, before releasing the reentry vehicles, is very short. It may be only a few seconds, and it may be no time at all.

In mid-course there are an incredible number of objects to attack. Each booster will presumably disgorge 10 reentry vehicles, and maybe many more decoys, so that the defense may have to attack 100,000 objects in space at one time. I believe that this is essentially impossible.

Warheads can be attacked in the reentry phase, when they approach their targets. This is what our old ABM (anti-ballistic-missile) system was intended to do. That system has been improved, but it is not Star Wars. It could effectively defend only hardened sites such as silos.

There are also three places where we might deploy our defense. If satellites were stationed in low orbits—up to about 1,000 kilometers above the Earth—only about 2 percent of them would be in sight of the Soviet missiles at any time. Therefore, an enormous number would have to be put into space, and their weapons would require a huge amount of fuel. For ordinary chemical lasers, I estimate—and this is totally unclassified—that approximately 300 satellites, each weighing 100 tons, would be needed. Just to bring 1 ton into orbit costs a million dollars, and the gadgets themselves would not be cheap. I doubt that this kind of defense could ever be less expensive than offense.

Lasers could be put into geosynchronous orbit, about 22,000 miles up, where they would remain stationary with respect to the Earth. There you would need many fewer satellites because they would be in sight of the Soviet missiles all the time. But this far from their targets, lasers would have to be unbelievably well focused. Hitting a missile from such a satellite would be equivalent to hitting a target one foot in diameter in Los Angeles from Boston.

In so-called "pop-up," you launch defensive weapons only when you detect an enemy attack. The trouble is that from any U.S. territory, it is very far to the Soviet missile silos. And given the way the Europeans have reacted to the deployment of Pershing II and cruise missiles, I do not believe they would accept further targets for the Soviets such as pop-up devices. By the time our defensive weapons are high enough to target the Soviet missiles, their boost phase will be over. The missiles will then be difficult to detect and will have dispersed into numerous reentry vehicles.

Many troubles may arise with defensive weapons. Will the mirror of the laser—a very delicate object—hold up? How can you find out whether the targets have been destroyed? The Soviets can fire their ICBMs so rapidly that our lasers cannot cope with them. They can build more missiles, intensifying the arms race. They can deploy space mines to destroy our defensive weapons.

At best, embarking on a space defense will nullify any attempts at arms control for 20 years. If we are successful, then after that period, the defense may have become superior to the offense. But more likely we will still have the arms race and offensive missiles will still threaten our country. It would be far less dangerous to reduce nuclear arsenals on both sides drastically.

**TELLER:** I agree that space-based battle stations, particularly in low orbit, make no sense—at least with present technology. But I disagree with other things Hans Bethe says about ballistic-missile defense. Unfortunately, I am hampered in explaining important new ideas because they are classified. Nevertheless, I can say that there might be some surprises in store as to the accuracy needed for a laser in geosynchronous orbit. And pop-up devices should be taken very seriously. They may be very effective, or at least force the opponent to undertake really expensive countermeasures. Although Bethe described these as easy, I doubt they are.

I also differ from him as to the possibilities of attacking missiles in their three phases. We have already greatly improved terminal defense—defense against warheads during reentry—and the Soviets have, too. They have placed it around Moscow and believe they can defend not only missile sites but their principal city as well. I agree with them that cities can be defended.

I think attacking reentry vehicles in midflight is also possible. Even 100,000 objects, if they are in space for half an hour, can be destroyed with weapons that shoot at the speed of light. There is a chance of distinguishing the decoys from real warheads: the magnificent new computing machines Japan plans to develop might be used for this. If we use the most ingenious methods to attack the missiles in the boost phase as well—if we do all these things—there is a real chance to create an effective ballistic-missile defense. We have neglected this chance too long.

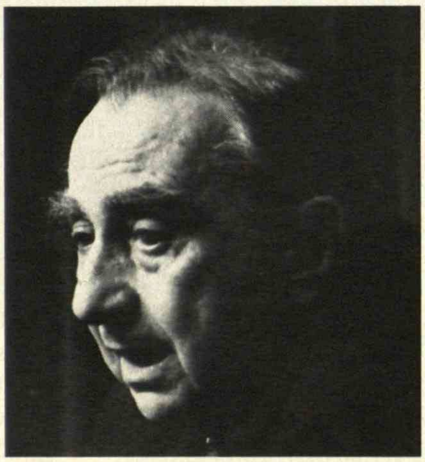
**BETHE:** I would be quite satisfied with a defense that is 80 percent effective, and not more expensive than the offense, but I don't even remotely see how that will come about. Consider the x-ray laser. It is based on sound physics, but the x-rays such a laser emits would have little effect on missiles. The numbers are of course classified, even though I calculated them in an unclassified way, but I can state that these x-rays will affect boosters very, very little. They don't penetrate very far into the atmosphere. All you need to do is to put a thin skirt of steel around the missile when it gets into space, and the x-rays will not harm it there.

I mention this less as a specific example than to show how every ballistic-missile defense that has been proposed can be countered inexpensively. I don't believe there is anything in sight—by which I mean within the next 20 years—that could make defense cheaper than offense.

The Fletcher committee, charged by the

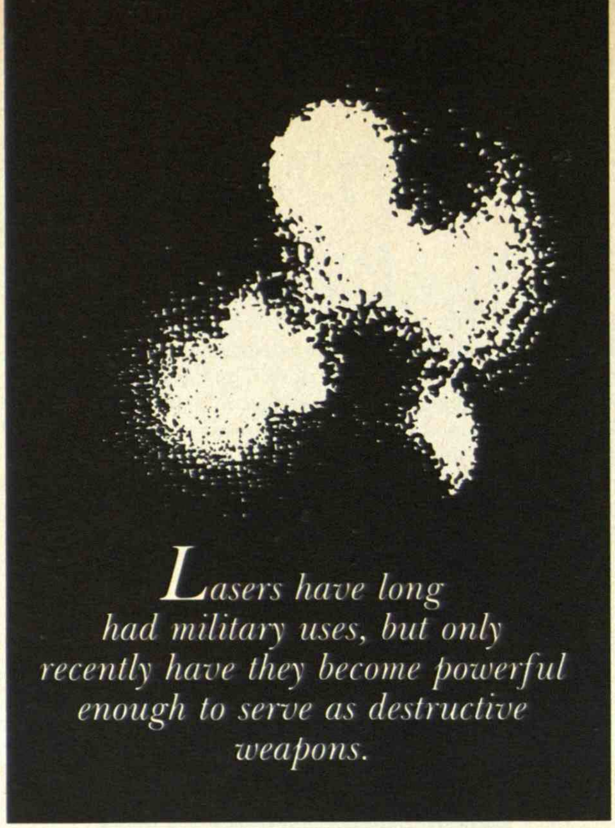
*(Continued on page 52)*

*Teller:*
*"We cannot afford* not *to defend ourselves."*



## THE FALLACY OF LASER DEFENSE

CONTINUED FROM PAGE 30




system would most likely not be finished before the turn of the century, he called it a "vision of the future which offers hope."

The president's speech signaled a radical shift in U.S. nuclear policy away from "mutual assured destruction" (MAD) as the basis of deterrence. Ever since signing the ABM Treaty in 1972, both superpowers have accepted the view that strategic stability requires each side to remain vulnerable to the retaliatory force of the other, thereby precluding any advantage in striking first. Indeed, efforts at "damage limitation," such as comprehensive ABM systems or even modest civil-defense measures, have usually been perceived as destabilizing.

Not surprisingly, Reagan's speech generated controversy. Conservatives such as Sen. Jesse Helms (R-NC) congratulated the president for "at last [giving] the signal to the military bureaucracy that it is permissible to think about defensive systems." But critics argued that the resurrection of ABM systems—renamed "ballistic-missile defense," or BMD—would be a quixotic and costly effort that would ultimately destabilize the strategic balance, leaving Americans less secure than before. The storm of controversy has escalated appreciably since those early reactions.

Reagan's proposal did not surprise everybody. Just one year previously, in a report titled *High Frontier: A New National Strategy*, the conservative Heritage Foundation advocated creating a space-based BMD system using "off-the-shelf" nonnuclear technology. However, although clearly influenced by the report, the president was careful not to endorse the foundation's approach. Instead, he supported the intensive development of futuristic "Star Wars" weapons such as high-energy lasers and particle beams.

One of the main reasons the superpowers agreed in 1972 to ban comprehensive ABM systems was that the technical obstacles to developing such systems seemed insurmountable. Even so, ABM research was allowed to continue because its absence could not be verified, and because each side wanted a hedge against secret breakthroughs by the other. In the 1960s and 1970s, the United States spent a total of $1.2 billion for R&D on high-energy lasers and other directed-energy weapons. After the Reagan administration took office, funding for this research jumped to over $400 million annually. This vast investment is finally beginning to pay off in prototype weapons systems with the potential for both antisatellite warfare and ballistic-missile defense. At present, work on laser systems is about 10 to 15 years ahead of research on particle beams.

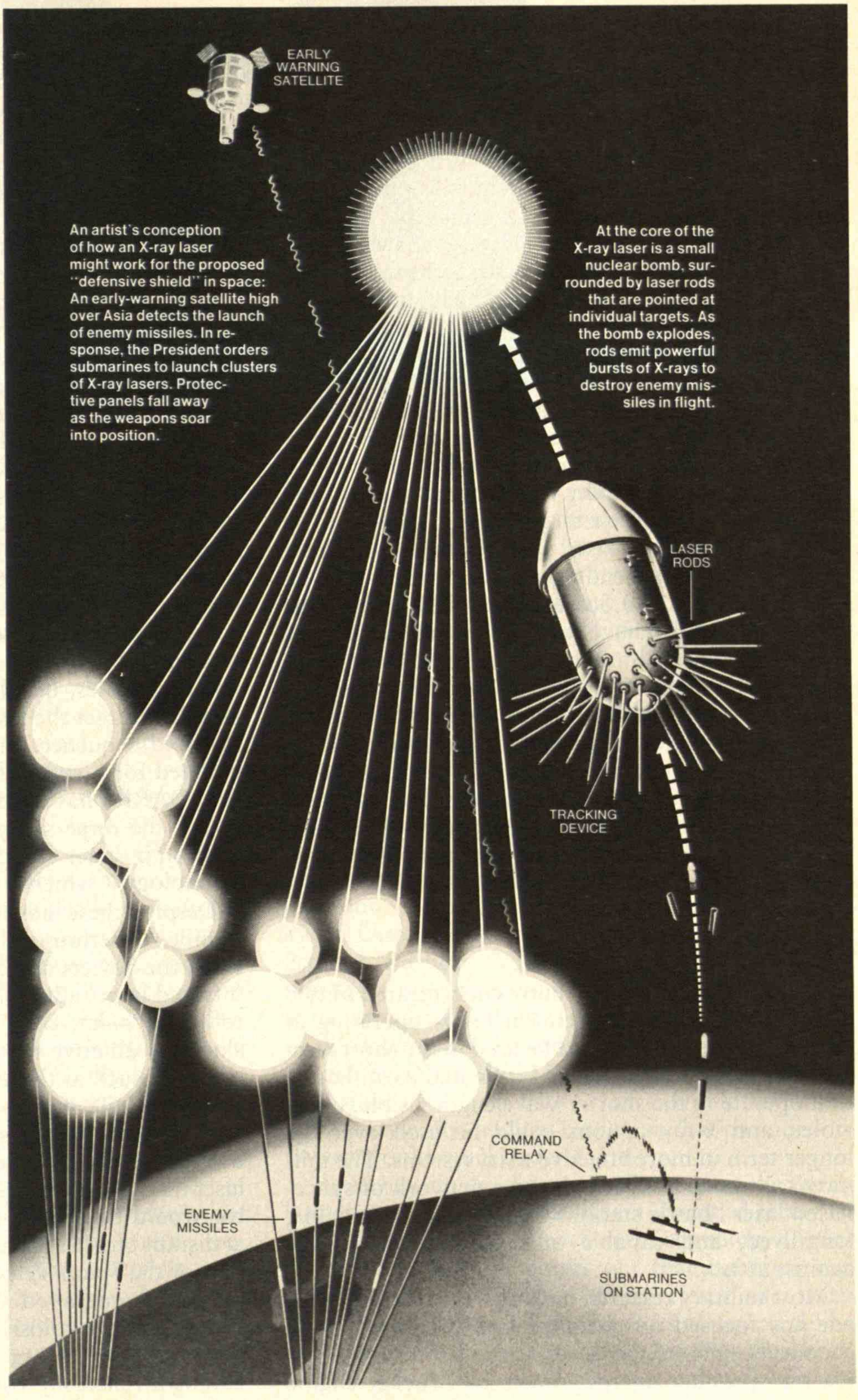
As the first tangible result of Reagan's March 23 speech, the Pentagon created a Defensive Technologies Study Team, headed by former NASA administrator James C. Fletcher and composed largely of government scientists. This team's aim was to evaluate the administration's goal of developing a space-based BMD system, and to suggest practical means for achieving it. In its report, submitted to the president last October, the study team was optimistic that "a robust, multitiered ballistic-missile defense system can eventually be made to work" using newly emerging technologies. The panel therefore urged the president to increase spending substantially for long-range R&D on directed-energy weapons, as well as on surveillance spacecraft and tracking systems to detect, monitor, and target Soviet missiles in flight.

Since then, the pace of events has quickened. In November the joint chiefs of staff recommended that the year-old Air Force Space Command be subsumed under a new, unified U.S. Space Command for all four armed services. And in December, Reagan and his National Security Council approved a five-year, $21 billion plan to begin more rapid development of a space-laser BMD system. This plan, including $2.1 billion for fiscal-year 1985, went to Congress in the recently submitted budget.

### The Way It Would Work

Lasers have long had many military uses, particularly in missile guidance and communications. But only recently have they become powerful enough to serve

**An artist provides one conception of how an x-ray laser system might work as part of a ballistic-missile defense. U.S. submarines would launch clusters of missiles in response to an early-warning satellite's sighting of the launch of enemy missiles. Each American missile would contain a small nuclear bomb, surrounded by laser rods pointing at individual target missiles. When the bomb exploded, the rods would emit powerful beams of x-rays to disable enemy missiles.**




as destructive weapons. The term laser stands for "light amplification by stimulated emission of radiation." A laser device generates a stream of light in which all the waves have exactly the same frequency and move completely in step with one another. Because of its perfect coherence, laser light can be focused into narrow beams that are intense enough to melt metal. To function as an interceptor weapon, the laser must be integrated with computerized control and optical systems that aim the beam precisely over vast distances and hold it steady on the target.

High-energy lasers offer many advantages over conventional anti-ballistic-missile systems because of their enormous speed and range. Although laser light would be diffused by clouds and fog if fired through the atmosphere, in space it should have a lethal range of thousands of miles. Moreover, in the time a laser beam traveling at the speed of light would take to flash 600 miles, a ballistic missile moving at 4.3 miles per second could progress only about 20 yards—too short a distance for it to take evasive action.

The trajectory of a ballistic missile, whether intercontinental (ICBM) or submarine - launched (SLBM), has three parts: boost phase, free fall, and reentry. Boost phase spans

DRAWING: DAN OSYCZKA, *THE NEW YORK TIMES*

the first five to seven minutes after launch, when the missile is lifted above the atmosphere and into space by first-, second-, and third-stage booster rockets, and kept on a precise course by its inertial guidance system. After reaching a speed appropriate to the distance to the target area, the exhausted third-stage booster fails away, leaving the missile's payload: a "bus" containing as many as ten multiple independently targeted reentry vehicles (MIRVs) armed with nuclear warheads. As the bus coasts through space, a very low thrust "post-boost vehicle" makes final course corrections. The bus then releases the conical reentry vehicles in programmed sequence, using the post-boost stage to direct each warhead on a separate trajectory. Unpowered and unguided, the MIRVs fall to earth under the influence of gravity. Reentering the atmosphere toward the end of their flight, they streak across the sky like glowing meteors and then explode over their targets.

To be effective, a laser BMD system would have to be capable of defending against a worst-case attack of about 2,000 Soviet ICBMs and SLBMs. The system would also have to strike the missiles during the last two or three minutes of the boost phase when they are above the atmosphere but still under rocket power. The reasons for this are threefold: once out of the atmosphere, the exhaust flames of the missile boosters could be tracked easily; the boosters would be far more vulnerable to laser energy than the hardened reentry vehicles they carry; and by destroying a booster, the laser would eliminate the entire cargo of MIRVs at once.

## Two Types of Lasers

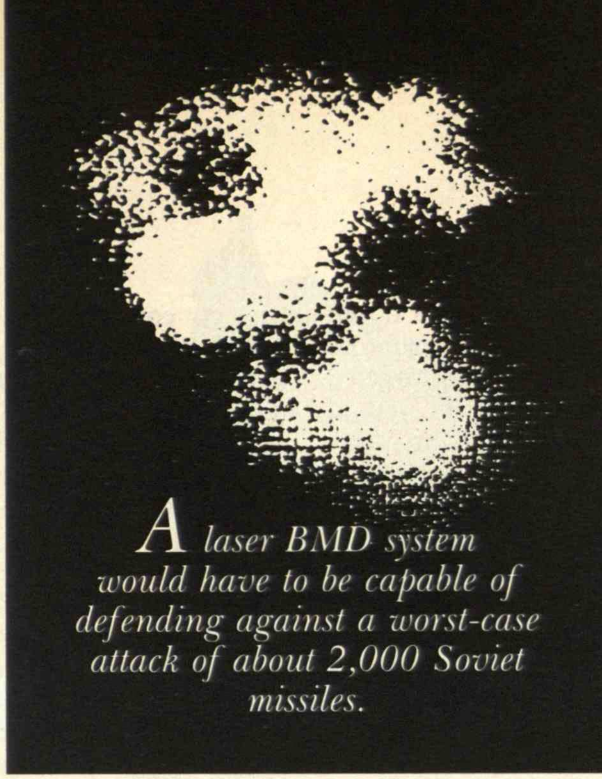
Laser BMD efforts are currently concentrated in two areas. High-efficiency chemical lasers operating at infrared wavelengths could be used in the short term as antisatellite weapons and for limited BMD. Lasers that operate in the shorter-wavelength visible, ultraviolet, and x-ray regions could be used over the longer term in more effective BMD systems. The military's ultimate goal is to build a network of space-based laser "battle stations" that would be reliable, long-lived, and capable of defending themselves against attack.

Most military research on lasers over the past decade has focused on chemical lasers, in which two chemicals such as the gases hydrogen and fluorine react to produce energy, much as a rocket engine functions. Chemical lasers would be well-suited for use in space because they require low temperatures and a vacuum to operate, and because the toxic wastes they produce would not pose a disposal problem. In principle the lasers would "kill" ballistic missiles by heating the metal skin of each missile until internal stresses caused the structure to fail or the fuel tank to explode.

To evaluate the feasibility of space-based chemical lasers, the Department of Defense's Advanced Research Projects Agency (DARPA) is coordinating a $200 million R&D effort known as the Space Laser Triad. As the name suggests, this research consists of three complementary projects. The first, designated Project Alpha, involves developing and testing a hydrogen-fluoride chemical laser that can produce 5 million watts of power and be scaled up to a size suitable for space-based BMD. The second prong, known as the Large Optics Demonstration Experiment (LODE), seeks to determine whether a large movable mirror can be used to focus a chemical laser precisely over great distances. The third project, code-named Talon Gold, is designed to develop a computerized system that will recognize and track hostile missiles, decide which ones to engage first, and then direct the laser beam against many targets in rapid sequence. Field tests of Talon Gold are planned for a space shuttle flight in 1986 or 1987. And DARPA has selected the Boeing Aerospace Co. to put the three subsystems together for a demonstration in space called "systems integration of triad technology," which could be tried as early as 1988.

Despite these advances, chemical lasers have a number of serious drawbacks for space-based BMD. First, the Soviets could protect their missiles against infrared laser radiation by coating them with highly reflective paint, or by covering them with a heat shield of ablative material or with thermal-protection tiles such as those used on the space shuttle. By sacrificing the weight of a few MIRVs, the Soviets could harden their missiles against infrared lasers by a factor of 10 or more. Second, because a chemical laser has a long wavelength, a 16-foot-diameter mirror would be needed to focus the beam and aim it at distant targets. Such a mirror would be larger than that of the Space Telescope, whose launch has been frequently delayed by technological problems. Third, unlike explosive interceptor missiles, a laser beam must hit its target precisely to be effective. The aiming mechanism would have to be accurate to less

than a yard over a range of 600 miles. Because even a slight jiggle of the beam would smear the laser energy over the target and reduce its impact, a laser battle station would require sophisticated stabilizers to compensate for the effects of steering the large optical system.



*A laser BMD system would have to be capable of defending against a worst-case attack of about 2,000 Soviet missiles.*

Short-wavelength lasers, whose development is about five to seven years behind that of chemical lasers, would be superior for space-based BMD for three reasons. First, because shorter wavelengths carry more energy and are absorbed by metal more readily, they would do more structural damage. Second, short-wavelength lasers produce a pulsed beam (rather than a continuous one) intense enough to vaporize metal at the surface of the target, generating powerful inertial forces that would tear the missile apart. Damage would occur much more quickly than with the overheating caused by infrared lasers, and could not be countered with heat-shielding materials. Third, more compact mirrors could be used to focus and steer a short-wavelength laser beam. A hydrogen-fluoride chemical laser produces light with a wavelength of 2.7 microns. By switching to a laser with a wavelength of 0.27 micron, close to the ultraviolet, the size of the mirror could be reduced by an order of magnitude, according to Gerald Ouellette, an aerospace consultant formerly with Draper Laboratories. Since the optical surface of the mirror must be accurate to well under the wavelength of the laser light, the precision of the mirror would also have to improve dramatically at shorter wavelengths. But by using a slightly larger mirror, the required degree of optical quality could be obtained.

The major drawback of short-wavelength lasers is that they need huge amounts of electricity—from tens to hundreds of megawatts. That means that large power sources must be used, along with "energy-staging devices" that can store electricity and then deliver it in enormous surges to power the laser pulse. Furthermore, all three types of short-wavelength lasers under investigation for BMD require hardware so complex that it is unclear whether it could be made compact or reliable enough for use in space. Excimer lasers need electron beams to produce their light, free-electron lasers require particle accelerators, and x-ray lasers intense enough for BMD would be powered by the explosion of low-yield hydrogen bombs, according to a proposal by the Lawrence Livermore National Laboratory.

The Livermore idea stems in part from a series of underground tests, code-named Dauphin and Cabra, conducted at the Nevada nuclear test site in 1981 and 1983. During these tests, a thin laser rod captured x-rays emitted by the explosion of a 40-kiloton thermonuclear warhead in a vacuum. The laser then amplified the x-rays to a power of several trillion watts—thousands of times higher than a conventional laser can manage—in the fraction of a second before the explosion vaporized the laser.

On the basis of this and other experiments, Livermore Director Edward Teller has proposed a design for an x-ray laser battle station named Excalibur. The station would consist of a low-yield nuclear warhead studded with about 50 small laser rods. Each rod would be mated with its own independent pointing and tracking system, enabling it to lock onto a single target missile up to 4,500 miles away. Once each laser was aimed at a separate target, the warhead would detonate, and an intense burst of x-ray pulses would beam from the laser rods at the attacking missiles. Theoretically, a single surge could destroy all the targets, despite their thermal hardening. A knockout punch would be essential, in fact, since each laser battle station would act in kamikaze style: the nuclear explosion that provided its power would quickly destroy it.

However, many physicists doubt than an x-ray laser system would work. Kosta Tsipis, director of M.I.T.'s Program in Science and Technology for International Security, points out that the laser rod vaporizes in the process of generating the x-ray pulse. As it does so, the rod loses its ability to define and aim the beam with precision. Another drawback is that the Soviets could counter the system by

launching their missiles in small volleys of a dozen at a time. The laser battle stations would therefore be forced to self-destruct before they had targeted their full complement of 50 missiles. Yet in spite of these and other problems, U.S. research on x-ray lasers is continuing at an annual cost of about $40 million.

### Organizing the Battle Stations

Even if space lasers can be made to work efficiently, organizing large numbers of laser battle stations into a comprehensive BMD system would be an extremely costly and difficult task. Each of the concepts proposed for a ballistic-missile defense has major technical or logistical drawbacks.

White House Science Advisor George A. Keyworth II has suggested stationing ground-based lasers throughout the countryside. Space-based relay mirrors would reflect the beams against rising Soviet missiles halfway across the globe. Since laser light does not readily penetrate clouds and fog, these ground-based lasers would be "fair-weather weapons," although several of them could be stationed in locations that are cloud-free most of the time. Nevertheless, only infrared and visible lasers would be suitable for this basing mode, as wavelengths shorter than 0.4 micron—such as the more powerful ultraviolet and x-rays—cannot penetrate even a cloud-free atmosphere.

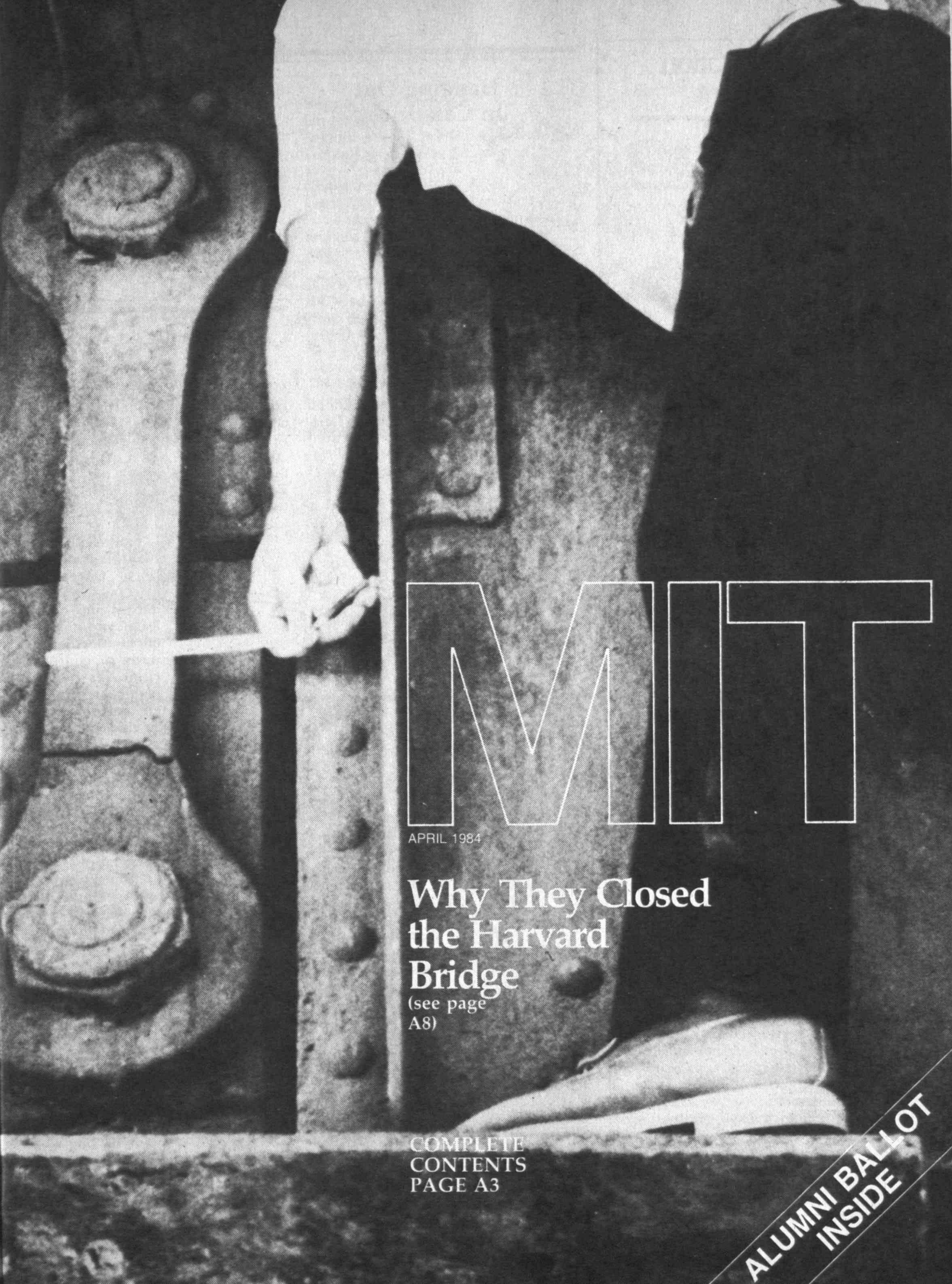
According to Keyworth, a computerized "adaptive-optics" system would correct for any incoherence of the laser beam caused by atmospheric disturbances. A sensor connected to the laser would detect such fluctuations by monitoring the "twinkle" of a reference beam sent down from a satellite overhead. A flexible mirror would then skew the laser beam slightly to compensate for distortions as they were detected. Although considerable progress is being made in the field of adaptive optics, Keyworth's proposal has been criticized because the system's orbiting relay mirrors would be vulnerable to antisatellite weapons, such as pellets or shrapnel traveling at high speed. A proposed alternative—basing the mirrors on rockets launched on warning—would not be feasible either, since the mirrors would not reach their working altitudes in time to fend off a missile attack.

A second basing mode also raises doubts. Teller has proposed that since x-ray lasers would be extremely compact, they could be housed in the nose cones of ballistic missiles. These include the proposed Midgetman ICBM force (*see "Midgetman: The Questioning Starts," February/March, page 81*) and submarine-based Trident missiles. Laser-equipped missiles would be launched into space in response to early warning of a missile attack. To destroy the Soviet missiles in their vulnerable boost phase, x-ray laser battle stations would have to reach an altitude of some 600 miles about five minutes after the missiles were launched. But that would demand an improbably rapid rate of acceleration. As Tsipis has pointed out, the missiles would need so much energy to get to their working altitudes fast enough that they would require enormous fuel tanks and hence would be difficult to launch.

Although x-ray battle stations could be launched into space in time to intercept free-falling MIRVs that had eluded a boost-phase defense, that mission would also be unlikely to succeed. The small size and high velocity of the reentry vehicles, as well as their lack of rocket exhaust, would make them difficult to detect and target. Moreover, because of the thick ablative heat shields on the MIRVs, they would be much more difficult to destroy than the booster itself.

A laser BMD system capable of attacking Soviet missiles in the vulnerable boost phase would therefore have to be based permanently in space. About 50 battle stations orbiting Earth at an altitude of about 600 miles would be needed for adequate geographical coverage. (Fewer battle stations would be required at higher altitudes; a system based at 6,000 miles, for example, could consist of just 20 stations.)

Because the laser platforms would be moving continuously relative to the Earth's surface, only a few would be in range of the Soviet Union when a missile attack began. Each battle station would therefore have to be capable of shooting down several hundred Soviet missiles without malfunctioning—an exceedingly demanding mission. Moreover, the system would have to work like a zone defense in basketball: as the Soviet missile fields fell in and out of range of the orbiting battle stations, the targets would have to be "handed over" from one laser platform to another about every 15 minutes. Thus, to create enough redundancy for the system to work reliably—with more than one laser targeting a given missile—the number of battle stations would probably have to be increased by a factor of 10 or more, at



# MIT

APRIL 1984

## Why They Closed the Harvard Bridge

(see page A8)

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ALUMNI BALLOT INSIDE

# Hanging Out In Cambridge

**Student View/Diana ben-Aaron**

Diana ben-Aaron, '85, is majoring in humanities and materials science. Her "Student View" appears regularly in this space, and she is also serving as features editor for Volume 104 of *The Tech*.

When Samuel P. Florman was an engineering student at Dartmouth, Robert Frost, who lived nearby, used to invite Dartmouth students to visit him at home in the evenings. Florman never accepted the offer, and today he infinitely regrets that folly. "My roommate would say, 'We're going over to Robert Frost's. Want to come?' And I'd say, 'No thanks. I have my thermo,'" Florman recalls.

The nearest thing at M.I.T. to Frost's "open evenings" is not in the Humanities Department but in a dusty, remote lab in Building 20, the Institute's back yard. There, Jerome Y. Lettvin, maverick professor of electrical engineering and biology, presides over a combined laboratory, library, and salon where the exchange of ideas is constant and far-ranging. And the door is almost always open.

The center of the lab is a table, a battle-scarred expanse of wood normally obscured by a sea of books, papers, soft-drink cans, and electronic parts. I have only once seen the table clean, and that was when an Israeli scientist in Lettvin's group took the law into his own hands and decided to tidy it up. Lettvin was plainly miffed at this attention to trivia. He jealously guarded his carton of cigarettes, frayed matchbook, and glass ashtray, fixing the Israeli through his double thickness spectacles with a baleful glare. "Every once in a while, it is good for it," said Gadi, indicating the cleared surface. A week later, equilibrium restored, you could again sit down at the table and find a paper on color theory, a clipping from the *New York Times*, an empty animal-cracker tin, a voltmeter, and *Livingston's Last Journals* within hand's reach.

The telephone on the table is rarely silent. Often the quickest way for Lettvin and his colleagues to answer a question, settle a dispute, or confirm a rumor is by telephone, and they use the instrument with an efficiency born of years of research. When I needed to know the number of chromosomes of the elephant, and had consulted sources from Harvard biology majors to the Boston Public Library without success, Jerry Lettvin determined the figure with a one-minute phone call.

"Jim?" he said into the phone. "How many chromosomes does an elephant have?" Silence. Lettvin looked up. "An African elephant or an Indian elephant?" he asked me. "He has to know."

*Please turn to page A15*

**"How many chromosomes does an elephant have?"**
**"An African elephant or an Indian elephant?"**

ILLUSTRATION: YAEL ZAKON-BOURKE

# MIT

APRIL 1984

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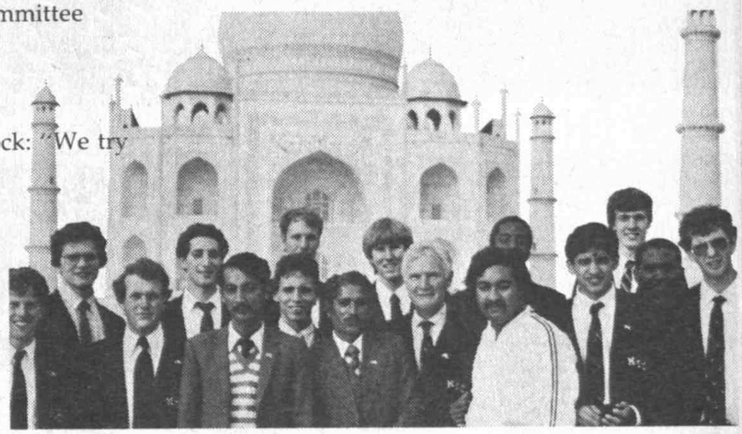

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## Letters

### Toronto and ~~Houston~~ Dallas in 1984

There are two errors in your account of plans for the 1984 National Alumni Conferences (*page A15, January*). You note that the two events will be held in Toronto (September 21-22) and Houston; but *Dallas* (October 12-13) is correct. And you note that this information may be of special interest to alumni in Chicago, when we hope in fact it is of special interest to alumni *everywhere*.
Joseph J. Martori
Cambridge, Mass.

### Sacrificing Truth to Politics

I have become increasingly alarmed at the attempts of government to solve problems demanding broad fundamental research—especially in the environmental arena—by the archaic methods of the adversary system of criminal law. Bits and pieces of evidence are assembled by federal funding on the one hand and by private funding from the opposition camp. The public's reaction is to seek solutions by lobbying to elect partisans or influence legislation, rather than by seeking to discover the truth. Meanwhile, despite a 5-percent increase in the percentage of the GNP spent by Washington in the last three years—a greater increase than in the preceding 18 years—a 12-percent cut in fundamental (for which read unprejudiced) research is being engineered.

In such an atmosphere neither science itself nor the professional integrity of the scientist can thrive. No scientist can legitimately be advocate to opposite sides of a controversy. This he may be forced to do, as the political climate changes, to secure the funding so necessary to the operation of a modern center of scientific and technical progress such as M.I.T.

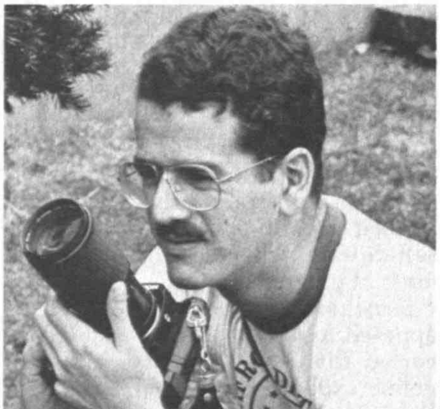
As an old-timer, I can remember when university scientists did not have to engage in the cut-throat business of soliciting research grants directed toward specific ends. Universities operated chiefly on unrestricted grants-in-aid from both industry and government and let their integrity and the merit of their self-determined programs carry the torch of progress.

Somehow the funding of research, as opposed to development, has to be divorced from political, legal, and economic expediency. The accumulation and assimilation of human knowledge cannot be turned on and off like a light bulb. Otherwise, science qualifies as a profession only by classing it with one that is traditionally even older.
Winslow H. Hartford, '30
Charlotte, N.C.

# "Wait by the Elevator. . . . Your Escort Will Meet You There"

## *How Davidoff Met the Technology Hackers Association*

By Donald M. Davidoff, '86



KEN FLOWERS

Donald M. Davidoff, '86, is a one-man photographer-writer team whose explorations of M.I.T. with camera and notebook are chiefly in behalf of *Technique*. He'll major in aeronautics and astronautics.

Practical jokes and pranks are sources of amusement on every U.S. campus. And we all know that such jokes—or "hacks" as we call them—have special style and pace at M.I.T.

So what's new about that?

Meet the Technology Hackers Association (THA).

Most of M.I.T.'s famous pranks were planned and performed by people who lived together—organized by the hierarchy within some dormitory or fraternity. That was true of the Model T reassembled on the roof of the East Campus parallels in the 1920s, the cow on the roof of Senior House in 1928, and the intrusion of an M.I.T. balloon into the 1982 Harvard-Yale game.

During the 1960s and 1970s, three living groups seemed to lead the way—East Campus (notably Third East), Alpha Tau Omega, and Baker House. A favorite activity at East Campus was "walling in" a room with bricks and mortar, thus forcing its occupants to utilize windows for entrance and exit. In 1973, one third-floor east resident returned home from a band trip to a sign on his door welcoming him back. Feeling a little suspicious, he carefully



ILLUSTRATION: JON MCINTOSH

opened the door to find a wishing well, complete with roof, bucket, and water. After being showered with pennies, he exclaimed, "Every student should have his own wishing well." The story carried on all the wire services, but unfortunately the well had to be dismantled by sledgehammer after it sprang a leak.

In 1967, ATO brothers found their way to the roof of the Sheraton Hotel for the purpose of advertising who had been there. To their surprise, the hack was easier than they anticipated. One flick of a switch and the letters S-H-E-R were off. Another switch darkened A-T-O-N for about a minute while the ATO team draped the "N." Ever since then, the fraternity has had an agreement with Sheraton to display only A-T-O during Rush Week.

Baker House is famous for its piano drop, in which a well-worn piano is released from six stories off the ground. In the late 1960s, Baker residents scored a special coup. A men's room was filled with snow on a cold night, and the Boston press was then notified of an amazing scientific discovery—a method of producing snow indoors by the use of steam from showers. The Boston *Herald Traveller* ran an exclusive and the wire services picked up the story before the hoax was revealed.

In February 1973, members of *The Tech* printed a facsimile of *Tech Talk* with a lead story announcing that President Jerome Wiesner had been appointed as science adviser to Richard Nixon and that Chancellor Paul Gray would replace him in the president's office. The papers were delivered to the media, and WBZ used the story in two morning newscasts. Only at noon was the copy changed to feature a hoax by M.I.T. students.

## *Can Hacking Be a Science?*

Will the future be different from this checkered past? Perhaps. During the past four years, an Institute-wide student organization devoted to all phases of hacking has quietly made its influence felt throughout the campus.

To the Technology Hackers Association (THA), hacking is broadly defined—student pranks, of course, but also control of Institute systems and exploration of the nooks and crannies of the campus. By their own count, members number over 75, with a nucleus of 20 to 30. They consider themselves to be "people who . . . tend to be ambitious and non-nerdlike"—their own words. These are not the "let's go out and get drunk" type. They're serious plotters—conscientious about purpose and actions and confident of their abilities.

When I sought an interview, I was instructed to be on the third floor of the Student Center at 9:45 p.m. of the agreed-on day. There the corridor phone rang.

"Please identify yourself," the voice said.

"Donald."

"Very well. Please proceed to Lobby 7, then head into Building 33. Take the stairs to the third floor. Wait by the elevator—you know where I mean?"

"Sure."

"Your escort will meet you there. Please don't be there before 9:55."

**Though the "Baker House piano drop" is not a product of the Technology Hackers Association, it meets THA's constitutional requirement that "no damage will be done in the course of hacking" . . . so long as the participants choose a sufficiently worn instrument.**

DONALD M. DAVIDOFF, '86

DONALD M. DAVIDOFF, '86

OREN LEVINE, '84, FROM TECHNIQUE

## "Take the stairs to the third floor. Wait by the elevator—you know where I mean?"

Five minutes after I arrived at the elevator, the door opened to deliver a student in black pants, black shirt, and dark sunglasses. He motioned me in and took me to the candlelit darkness of the William B. Given, Jr., Lounge on the fifth floor, where we drank sherry and talked about hacking and THA. I was impressed from the start: without bypassing a lock in the elevator, it will not go to the fifth floor at night, and the door to the lounge is always locked after 5 o'clock.

The seriousness of the organization is manifested in both its structure and its achievements. Though one officer emphasized that "bureaucracy is kept to a minimum," I found that there are seven officers—president, responsible for supervising and coordinating possible activities with other schools in the area; chancellor—the chief executive officer, the member with the most authority; vice-chancellor; and scribe—responsible for maintaining THA's extensive records, and three others. The members specialize in one of three ministries: intelligence, external affairs, and finances, each with its own directorates. There also exists a team of six hackers with exceptional climbing ability and other talents who comprise Special Services. My interview was with the president, chancellor, vice-chancellor, and director of Special Services.

First, I learned that the organization makes a major effort to assure a prolonged existence—a system of recruiting. Students around the Institute who are observed to possess certain potentially useful abilities—or who are found roaming about as THA members do their thing—are invited to join.

THA also helps with the "Orange Tours," late-night excursions to roofs, tunnels, and other off-limits places around the Institute conducted by an East Campus group during orientation week to give freshmen an alternative view of the campus. Despite weekly meetings and time devoted to the hacks themselves, almost all THA members do in fact graduate in eight terms. They view THA as "supplementary" to school work;—"a creative outlet"; indeed, they say, "school work interwines with hacking." They point out the obvious need for practical skills—such as electronics to disarm alarms around the Institute.

One officer, a Course XV major, calls THA "quite an experience. The opportunity for management experience is amazing. It is necessary to plan, communicate, and execute. You can only do what you can convince others to do with you."

THA's constitution states that no damage will be done in the course of hacking, and that hacking should never be malicious in nature. In fact, I was told, "Physical Plant often does more damage taking [a hack] down than anyone could possibly do putting it up."

An example of this was when THA installed a working telephone booth on the Great Dome in 1982. When officials went to examine the telephone, it rang. The booth was

**The THA strikes again: startled pedestrians in the lobby of Building 7 found themselves showered with ping pong balls pouring from the top of the dome above them—nearly 500 in three minutes—on April 1, 1983.**

DONALD M. DAVIDOFF, '86, FROM TECHNIQUE

**"The opportunity for management experience is amazing. . . . You can only do what you can convince others to do with you."**

placed very carefully so that it could be returned to its origin in safe, operable condition. But Physical Plant, in its haste to remove the hack, blew it by doing significant damage.

THA generally tackles one major hack each term—and approximately six minor hacks. All are always exceedingly well planned, with rehearsals and trial runs. Communication is always extensive through signals, walkie-talkies, and telephones.

## *The Happy Radome Hack*

All of the planning, communications, and security paid off during the "happy radome hack" of May 9, 1983. That night THA made its second attempt to place a smiley face over the radome on the top of the Green Building. The first had been unsuccessful due to undermanning and heavy winds.

A ground crew of 5 inside and outside of Buildings 14 and 66 served as lookouts. One member stayed inside the Green Building basement to watch for potential trouble. Teams within a roof crew of 10 were assigned to put the face on, to disarm the microwave motion detector alarms on the top two floors of the building, and to man a radio eavesdropping on Campus Patrol's radio.

(A near-hitch: the eavesdroppers forgot the Campus Patrol's frequencies. But some quick thinking led to a call to Campus Patrol from an unidentified THA member. He was working, he said, on a 6.111 laboratory project that used the C.P.'s frequency as input, but he didn't know the frequency. The needed channel was cheerfully given.) The operation started at about 11:00 p.m. and was completed by 1:50 a.m. The face that greeted the community on May 9 stayed on until 11:40 a.m. Indeed, the Green Building has been a tempting target for many hacks, and its elevator was once rewired to THA's own switch. When a hacker flipped the switch, the Campus Patrol's alarm was deactivated, the elevator was called, and the hacker was brought to the roof.

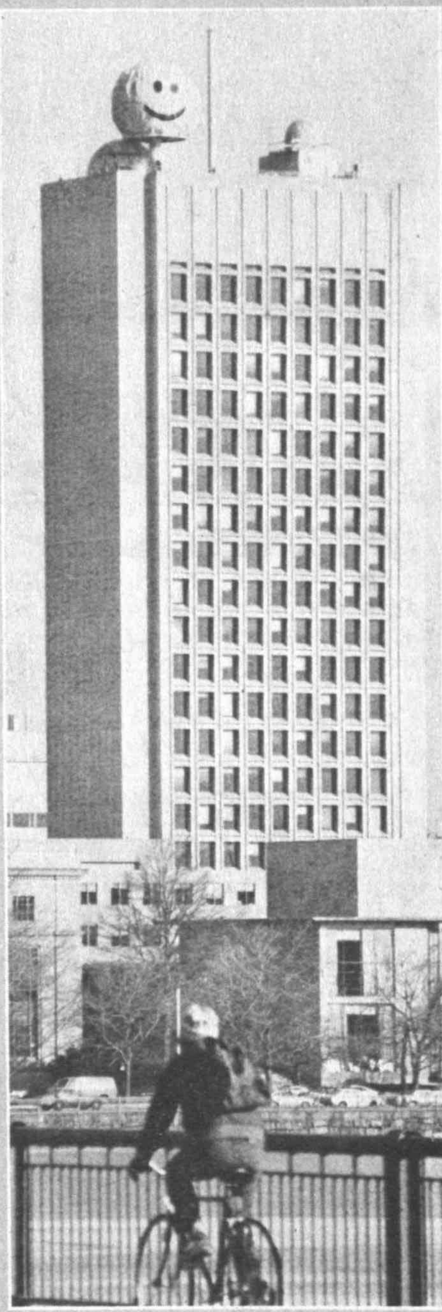
Creativity and subtlety are the trademarks THA seeks. One summer, the automatic sprinkler system on Briggs Field was rewired so that water started spraying out around home plate in the middle of a baseball game. A Christmas tree appeared on the top of the Great Dome during one April snowstorm. (This may seem simple for such a talented group, but this particular hack posed three difficult problems: the tree had to be dragged up many flights of stairs unnoticed, the ice on the dome had to be chipped away to safely reach the top, and the tree had to be tied down in wind and cold and darkness.)

Despite all these activities, its senior officers insist that THA has an amicable relationship with the Campus Police. Furthermore, they insist THA has the best interests of the Institute at heart.

During the course of normal exploration, THA became aware that the Admissions Office was accessible through a window. One night, members took advantage of the breach and notified the Institute in their own unique way. The problem was soon corrected. Members constantly "look for openings and inform police through anonymous channels."

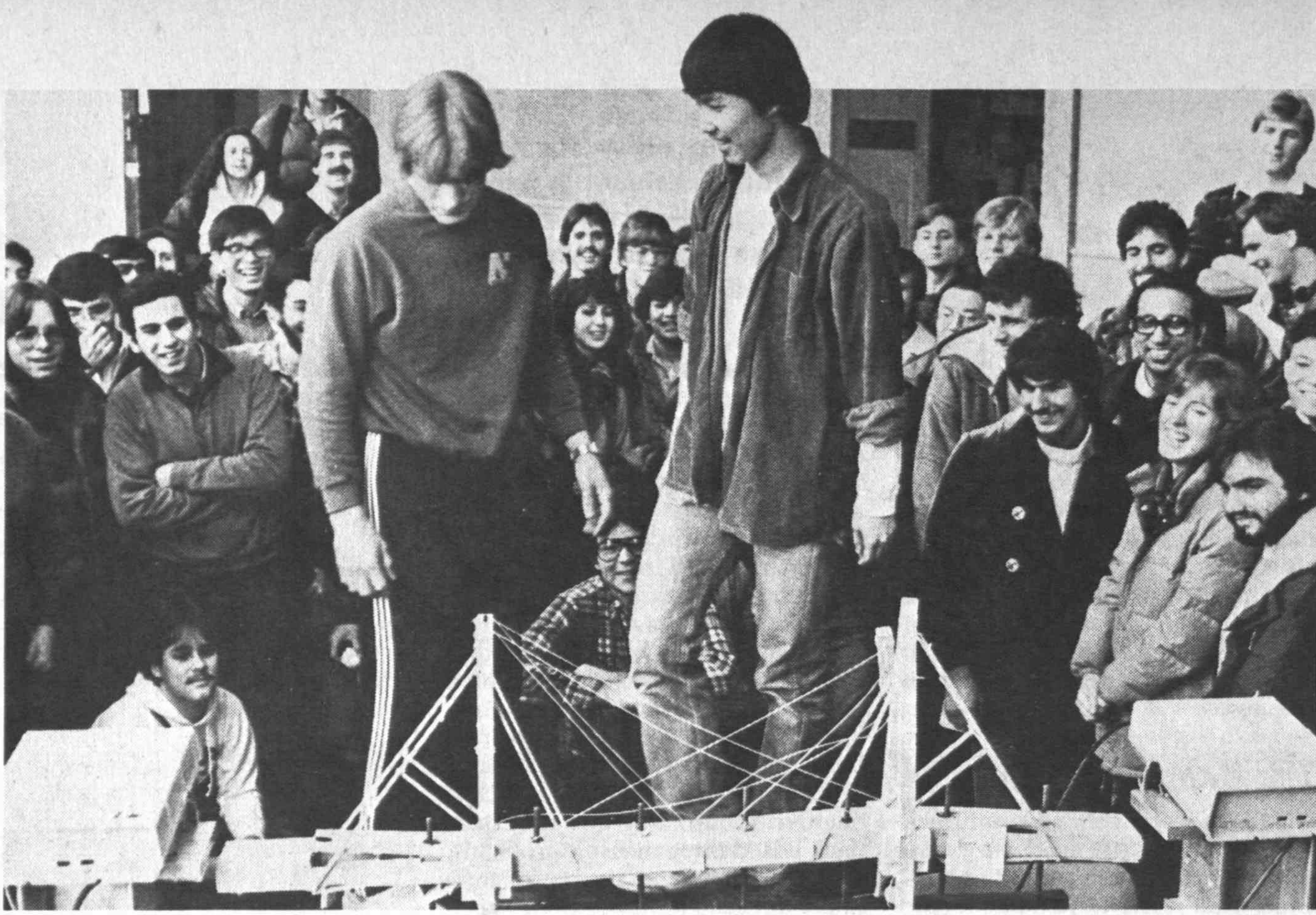
"Some groups get their jollies vandalizing," says the chancellor, "but THA is different." In fact, in an effort to insure that THA is not circumstantially blamed for the actions of others, the organization tries to be aware of the activities of other hackers and discourage damaging and tasteless pranks.

"Looking up at the smiley face was a great thrill," the chancellor told me—"a sense of pride and accomplishment."



ROHAN KHALEEL, '85, FROM THE TECH

**The "happy radome hack" of May 9, 1983, required the talents of 15 members of the Technology Hackers Association—10 on the roof and 5 on the ground. And, as author Davidoff explains, one of the latter had to do some quick thinking.**



CALVIN CAMPBELL

# The Rights and Wrongs of Bridges

## *Hands-on Engineering in the Spotlight*

When a bridge falls, everyone wonders. For an engineer, the curiosity is stronger, the question direct: Why?

For M.I.T., that question came close to home last summer when, in the aftermath of the Mianus River bridge failure in Connecticut, traffic on the Harvard Bridge was reduced from four lanes to two, with trucks and buses embargoed completely.

What's wrong? Is it really dangerous? How can it be fixed? When? Did someone goof? Why?

To capitalize on this new curiosity about a field that many of us think is pretty old-hat, the Civil Engineering Department turned a special spotlight on bridges during the 1984 Independent Activities Period. There was a renewal of the traditional "build-your-own-bridge-model" contest for students, followed by a full-scale professional symposium on the plight of the Havard Bridge, bridge problems in general, and modern trends in bridgebuilding.

Professor John H. Slater, '78, issued bridgebuilding kits—pine beams, balsawood planks, string, epoxy, and miscellaneous hardware—to ten teams of students. With the kits came a challenge: design and build the strongest, lightest bridge you can to span the 44-inch gap on a special testing table.

The model bridges had to accommodate movement of up to half an inch in the height of the foundations on which they would carry their loads (real bridge piers may move just that way if soil conditions are poor, Slater noted—one of the challenges to real bridge designers). In three weeks the models would be tested to failure.

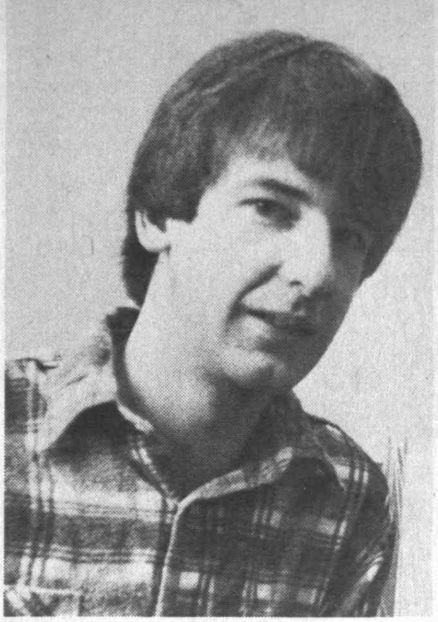
The best bridges would be the strongest ones. And the best of the strongest would be the lightest—in other words, the most efficient in its use of materials.

### They Prestressed Their Twine

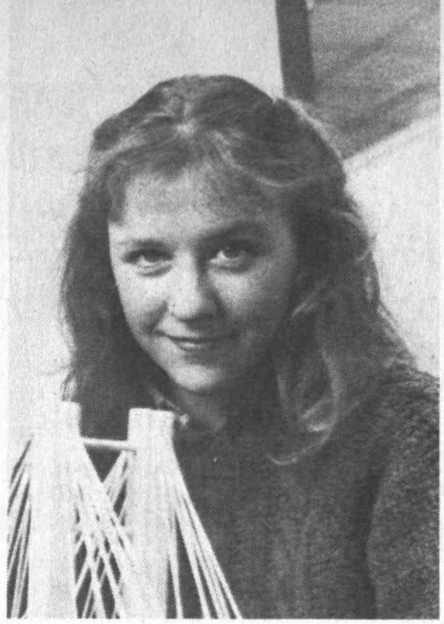
It's not that such a contest turns amateurs into professional bridgebuilders in three weeks, says Professor Slater. But it's a good deal more than just fun, he insists—a kind of open-ended learning that may be unique in each student's experience, for every team has to decide between more options than most engineers can ever consider—suspension bridges, simple trusses, cantilevers . . .

The winning bridge was a cable-stayed truss with a central tower, the work of Marjorie Ferguson, '84, and Allan P. Bommer, '84. Together they did what Professor Slater calls "an exceptional job." Their bridge weighed only 1.66 pounds—they'd been given at least 2.5 pounds of material to work with—and it carried the phenomenal load of 3,700 pounds.

It was Bommer's second effort. In last year's contest he and a different teammate were at the bottom: their bridge was the weakest of all. This year Ferguson and Bommer picked what Slater thinks is "the most efficient structural form," and they worked hard to make it right. Their cotton twine was "pre-



**For those who did it—and even for those who only watched—engineering came to life in the January bridge-building contest. Marjorie Ferguson, '84, and Allan P. Bommer, '84 (this page), won by using only 1.66 pounds of wood, string, and hardware to build a model that carried 3,700 pounds. Runners-up (opposite) were Mark Gebert, '86 (left) and John Y. Wang, '86, whose 2.11-pound bridge broke at 2,300 pounds.**



stressed"—soaked in water and fastened with care to the beams and decking. It's that sort of thing that learning is all about, thinks Professor Slater.

Bommer agrees—to an extent. "Some of what you learn is engineering, and some of it's model-building," he says.

Civil engineering students may have an advantage in the contest, but it's by no means an overwhelming one. The runners-up in this year's contest, with a 2.11-pound model that carried a 2,300-pound load, were John Y. Wang, '86, and Mark Gebert, '86; Wang's major is mechanical engineering, Gebert's chemical engineering. A few days earlier Wang had won another IAP contest by designing the most efficient winged keel (as in *Australia II*) for a racing yacht.

### The Severed I-Bar

The answer to those questions about the Harvard Bridge? Well, all it took was a single photograph (*see cover*) by Ronald F. Brodrick, '48, of Teledyne Engineering Services, Waltham. Professor Kenneth Leet, Sc.D. '64, of Northeastern University, who has a special passion for the Harvard Bridge, explained that most of its spans rest directly on the familiar stone piers, whose strength and integrity is not in doubt. But between two pairs of widely-spaced piers there are spans literally hung from their neighbors. The hanging is done with I-bars and pins—exactly the same detail as in the Mianus River bridge that failed so spectacularly, except that more redundancy was designed into the Harvard Bridge.

Hurried inspection after the Connecticut tragedy revealed two of the I-bars on the Harvard Bridge cracked—one shown on the cover, the other on the far corner of the same span. Reason enough to reduce the traffic and send for the engineers; a bridge without this one's redundancy would have collapsed as did the one in Connecticut. It was fatigue failure, thinks Brodrick—probably the result of corrosion that seized the pins which did not allow the I-bars to move as the traffic varies and the seasons change.

Now the bridge is to be rebuilt—a complete new superstructure above the piers. The complete replacement is recommended because all the iron and steel in the bridge is obsolete, weaker than modern loads require. New materials and new structural details, said Alexander L. Pavlo, '31, whose firm has completed the new design, will make the new bridge stronger and more efficient than its predecessor—though the appearance will hardly be changed at all. The job will start in something over a year.

Meanwhile, what about the rest of the nation's elderly bridges?

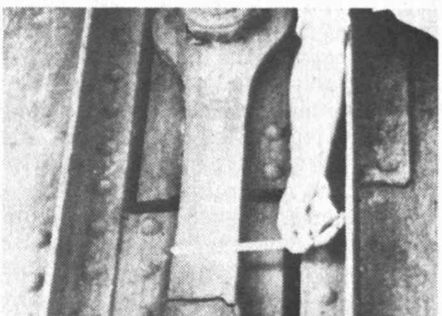
For every problem there's an opportunity, says Professor Jerome J. Connor, Jr., '53. The opportunities in this case are legion, he says: better training for maintenance personnel, new techniques of rehabilitating structures without disturbing the flow of traffic, research on new weatherproofing (corrosion from water and salt is the single largest cause of bridge problems), and new programs for computers to help engineers model deterioration and to assure the quality of complex structures.

The technology of bridges is changing, too, said Oral Buyukozturk, associate professor of civil engineering. Consider, for example, the concrete segmental bridge. Basically, it's prefabricated. The concrete is poured into sections off-site, and the sections are then mated on-site to construct the span. The technique, which has been used for roughly 100 U.S. bridges during the past ten years, saves money and time. But it requires high technology and sophisticated engineering analysis, and experience is still so limited that no one is certain of the long-term performance of segmental bridges, Buyukozturk cautioned.

### Hands-On Technology

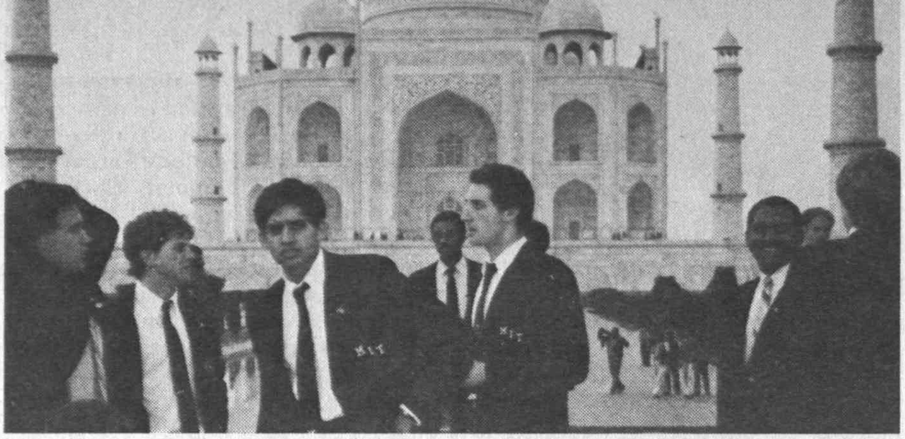
Clearly, there's more to bridges than meets the eye of their casual users, and that was Slater's message to an engineering community most of whose members seem to be drawn to the modern exotics—more and more semiconductors, transistors, and diodes arranged on smaller and smaller chips of silicon.

In other words, for hands-on technology, try a bridge.



RONALD F. BRODRICK, '48

**Why close the Harvard Bridge? A single photograph answers. Two spans of the bridge in M.I.T.'s front yard are suspended from their neighbors with I-bars—much like the infamous Mianus River bridge. When the latter failed, inspectors found fatigue cracks in two of eight I-bars (one shown above) carrying a single Harvard Bridge span.**



*The Varsity Basketball Team Wins a Few Games and Many Friends on a Whirlwind Exhibition Tour of India*

# If It's Thursday This Must Be Madras

**By Ken Cerino**

How many college athletes can tell of playing basketball in nine Indian cities, meeting Prime Minister Indira Gandhi, and visiting the Taj Mahal?

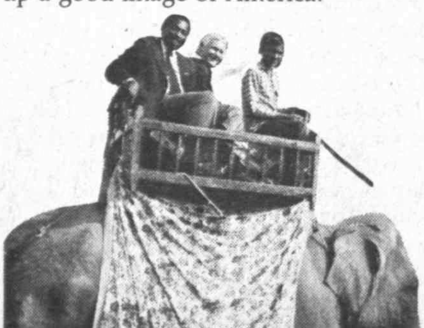
Around the halls of M.I.T. this spring the answer is quick to come: 13, plus manager, head coach, and assistant coach. They're members of the 1983-84 men's varsity team, and players and coaches alike describe their January trip to play exhibition basketball in India as "a thrill of a lifetime."

It was hard work—97 1/2 hours spent traveling 20,419 miles to play nine games in 12 days. That record, and the team's confidence that "we represented M.I.T. and our country as well" (*see James W. Bishop's diary, beginning on the opposite page*) far overshadows in everyone's memories the disappointment of winning only three of nine games.

Indeed the success of the trip is not to be measured in miles, wins and losses. The M.I.T. players had a once-in-a-lifetime opportunity to travel to a foreign land and help a country develop its national basketball program while furthering international good will.

**More Than "a Bunch of Jocks"**

According to Leonard Milton, president of the People-to-People Sports Committee that arranged the trip, M.I.T. was picked because "we didn't want to send a school with just a bunch of jocks. These are intelligent guys and they put up a good image of America."



It worked. During their trek throughout India, the Engineers endured eight domestic airline flights, nine bus trips, two train rides, and some sleepless nights (and lots more short ones) to win the admiration of thousands of Indian fans.

M.I.T. competes on the Division III level in basketball in the United States (Boston College and UCLA, for example, are considered Division I) and is certainly no national powerhouse, but the Indians treated the M.I.T. players like Olympic champions.

"They gave us a parade in Tuticorin on the back of an open truck with firecrackers popping," recalls Fran O'Brien, coach. "About 8,000 people watched the game from makeshift bleachers and we won by two points. Afterwards, kids and older people wanted to touch the American players and get autographs.

"The Indian people really glorify American basketball, and everywhere we went the signs said 'India vs. U.S.A' with only little print at the bottom saying 'M.I.T.' "

The first view of the country was unforgettable, says O'Brien—"Calicut, a city of some million-and-a-half residents, reflects the main problems of India: high unemployment and impoverished people with thousands struggling for survival." The trip's basketball began there against a team which featured a 7-foot-5-inch center (with a 7-foot-three-inch backup, compared to M.I.T.'s tallest at six feet nine inches) and several players 30 years old and older. There and elsewhere most games were played outdoors in temperatures approaching 100°F.

But "we were developing a relationship with a proud people, full of warmth and hospitality," says O'Brien. "I will never forget the children of India, the real jewels of this great country. In their eyes, I saw the heart and soul of a group who someday will lead this nation to greatness."

**"Better Players, Better People"**

"About 20 cities showed an interest in playing us, so in order to appease the Basketball Federation of India, we agreed to nine games in the 12 days. Add all the hours spent travelling to various towns, food problems, and lack of purified water, and I became quite concerned about the health of our players, many of whom experienced dysentery and loss of weight. But throughout the trip everyone handled all the adversities extremely well. The players' spirit and enthusiasm remained constant and they represented themselves, their university, and their country well. I was especially proud of their relationships with the Indian players and fans who attended our games.

"The quality of our play steadily improved throughout the trip. One of the main objectives on this venture was to develop as a team so that the remainder of our American schedule could be handled with more promise and intensity. We came home a much better team. And more importantly, we came home better people for our experiences."

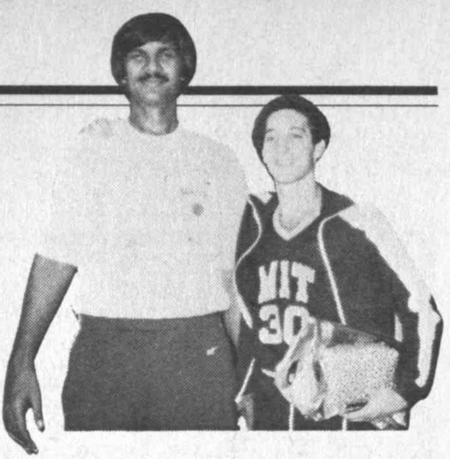
M.I.T. players making the trip: co-captains Mark Johnson, '84 and Chris Wilson, '84 along with John Shivanandan, '84, Greg Bartlett, '85, Jeff Bornstein, '85, Bud Taddiken, '85, Charlie Theuer, '85, Jim Egan, '86, Randy Nelson, '86, Craig Poole, '86, Alex Romeo, '86, Mike McElroy, '87, and Evan Pratt, '87. On board: assistant coach Leo Osgood and James Bishop, '84, manager.

*KEN CERINO is director of sports information at M.I.T.*

# "A Road Trip to Remember, A Thrill of a Lifetime"

## *Fifteen Days of Basketball in India*

**By James W. Bishop, '84**



*Bottom, opposite:* **Assistant Coach Leo Osgood and Coach Fran O'Brien testing local transport in Agra.**

*Top, this page:* **India's "tower of power," 7'5" Sunil Panda, with M.I.T. guard Jeff Bornstein, '85 (6'3").**

*Below, this page:* **Camel-rider Greg Bartlett, '85, guard.**

**Calicut, December 31**—We stayed at the Alakapuri Guest House, which was a nice place although it had ants. They also didn't have mineral water, a fact which didn't fully affect us until later. The New Year arrived during our evening meal, and all the lights in the guest house were turned off for a few seconds. We celebrated New Year's again the next morning at 10:30 a.m. (which was midnight in Boston).

**Calicut, January 1**—Our first practice in the indoor stadium didn't go well because people were still groggy from the trip. Mark Johnson, our 6'9" center, was the first player to get sick. After practice, reporters swamped us for interviews and took a team picture which appeared in the sports page the next day. One kid asked me if we would be playing in the Olympic Games this summer.

**Calicut, January 2**—Our first game: we played the Indian National All-Stars and lost, 88-62. Before the game, there was a ceremony where we marched in and walked around the court and then back to the center circle for a wave to the fans; John Shivanandan carried the American flag for us. The Indian squad marched in in the same way, and then all the players were introduced and we exchanged "tokens." After the game, the players again were introduced and presented gifts which they referred to as "the memento."

**Tellichery, January 3**—We rode with our opponents to the next game, and before the contest 7'5" Sunil Panda of the Indian team had his picture taken with our 5'7" guard Jim Egan. The Indians have divided their national team into two all-star squads for the exhibition series against us—the White and Blue teams. Here we played the White squad (the better of the two) and lost 76-60 before a crowd of approximately 5,000 people. The stadium was outdoors, the floor concrete, the lighting good, but crickets frequented the court during the game.

**Ernakulam, January 4**—We lost to the Blue team, 75-66, in this suburb of Cochin. Again we played outdoors on a concrete court, but this time the lighting was poor. The capacity was about 2,000 and it was overflowing. We stayed at the Polakulath Tourist Home, which was dirty, had bugs, no hot water, and no air conditioning.

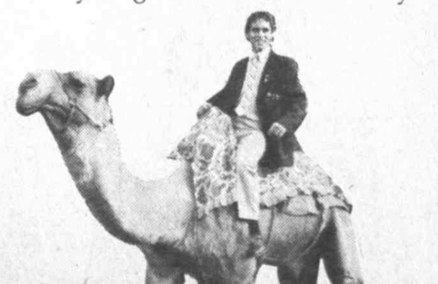
**Madras, January 5**—Madras seemed like a paradise—four- and six-lane roads! Our evening game was at the gym of a local university that had an unfinished and very uneven wooden floor and temporary stands that held about 3,000 people. The place was packed. The ceremony was the same, but we had to sit in a second row of chairs back from the court because the local dignitaries sat in the first row. I told our Indian organizer what I thought about the politicians, but to no avail. We were fortunate, though, that one of the pols was U.S. Information Officer Merrill S. Miller. He brought us water from the American Consulate, and this made us feel better. We played well but lost a close game, 67-63.

**Tuticorin, January 6**—We flew from Madras to Madurai and then took a bus to Tuticorin. Why we went this way instead of going straight here from Cochin is beyond my comprehension. As soon as we got off the bus the Indian officials put us on the back of a truck, and we had a parade through the city with firecrackers popping all around. We waved to the people, and it was quite an experience. We checked into the Sagar Sadan Guest House which turned out to be a high-security company-run place for executives and military-types—quite nice with all the necessities of a good hotel except no mineral water. They did make us some tea which we brought to the game. The game was one of the high points, as we beat the Blue team, 58-56, before 8,000 people in a temporary stadium built in the sand of poles and branches nailed together. At the end of the game hundreds of fans—especially children—wanted our autographs and handshakes. It was very moving. Back at the guest house, a representative from Neyveli (the next stop on our tour) pleaded with us to play again the next day (which would make six games in six days in six different cities). We wanted a day's rest, but this guy said all the arrangements had been made, the fans were expecting us to show up, and the trip to Neyveli was only seven hours by bus. We finally agreed, packed our bags, and left at 2 a.m.

**"At the end of the game hundreds of fans—especially children—wanted our autographs and handshakes. It was very moving."**

**Neyveli, January 7**—We finally arrived here at 4 p.m. after a series of frustrating stops and delays—14 hours to travel 260 miles! This is a complete company town run by the Neyveli Lignite Corp., and everywhere there are signs exhorting people to greater efficiency, more loyalty to the company, and smaller families. My favorite was, "A small family is a happy family." As expected, our tired players lost to the Blue team, 70-55.

**Calcutta, January 8**—We arrived here at 11 p.m. after taking a bus to Madras and a plane for a two-hour flight. The State Government Circuit House had some clean rooms and was protected by a gate, yet some poor people slept in the hallways. Fortunately, we didn't stay there very long. This was our first day



**Fifteen Days in India**

Continued from page A11

off in a week but we had spent all of it traveling to get ready for three more games.

**Jamshedpur, January 9**—Jamshedpur is a steel town, and it has very poor and dirty sections adjacent to wealthy and clean sections. We stayed in the Tata Industries Steel Company Guest House, the wealthy part of town. Everyone was extremely tired, but they asked us to play that night, saying they feared a possible riot if we didn't show up. We had our uniforms cleaned for the first time since we arrived, but they came back wet, so we wore our practice uniforms. The 3,000 or so people who showed up for the game weren't very enthusiastic and they certainly wouldn't have started a riot, but we rose to the occasion and beat the Indian Junior National All-Stars, 68-54.

**Jamshedpur, January 10**—We had a reception at the Regional Institute of Technology, then toured a steel mill, and when we returned to the guest house our laundry had been delivered and for the first time we had clean uniforms. We played our best game that night, beating the White team, 69-68, before 4,000 people. We held Panda, their big center, to only eight points. After the game, crowds of people gathered around us asking for autographs. Jim Egan and Greg Bartlett were looking for some flowers to present to some Indian girls who had been cheering for them the entire game.

**New Delhi, January 12**—In the morning we met Ambassador Harry G. Barnes, Jr. at the U.S. Embassy, and we gave him some paperweights from the M.I.T. Museum. We had an afternoon game (which was delayed by rain) and lost to the Delhi All-Stars, 69-68. Afterwards we went shopping and finally had a chance to relax.

**New Delhi, January 13**—At 8:30 this morning we saw Prime Minister Indira Gandhi at her home—a small place with light security: they didn't even search our bags. Leonard Milton, president of the People-to-People Sports Committee which arranged our trip, described our visit and we gave Mrs. Gandhi a large trophy and letters from President Paul Gray, Massachusetts Governor Michael Dukakis, Speaker Tip O'Neill, Senators Edward Kennedy and Paul Tsongas, and Cambridge Mayor Alfred Vellucci. Mrs. Gandhi was a pleasant person and a gracious hostess. Then to Agra to see the Taj Mahal. There were monkeys who would beg for peanuts and jump on your head if you didn't give them any, and Greg Bartlett took a camel ride, and some of the players and coaches took elephant rides.

We were invited to India for one primary purpose: to help improve Indian basketball. A secondary purpose was to further the goodwill between the people of India and the United States. We fulfilled these objectives by playing a series of games against the top Indian players in several different towns. For all of us, it was a road trip to remember, a thrill of a lifetime, and I think we represented M.I.T. and our country well.

*JAMES W. BISHOP, '84, from Huntsville, Ala., is completing his fourth year as manager of the M.I.T. men's basketball team and served as M.I.T.'s travelling secretary during the team's visit to India. He also serves as manager of the baseball squad and is a statistician for the football team. His major is electrical engineering and computer science.*

## Travelling Athletes: Wrestlers to Mexico, Swimmers to Puerto Rico

While M.I.T.'s men's basketball team was in India (*see pages A10-A12*), three other varsity sports teams took advantage of the 1984 Indepedent Activities Period to make trips outside the continental United States.

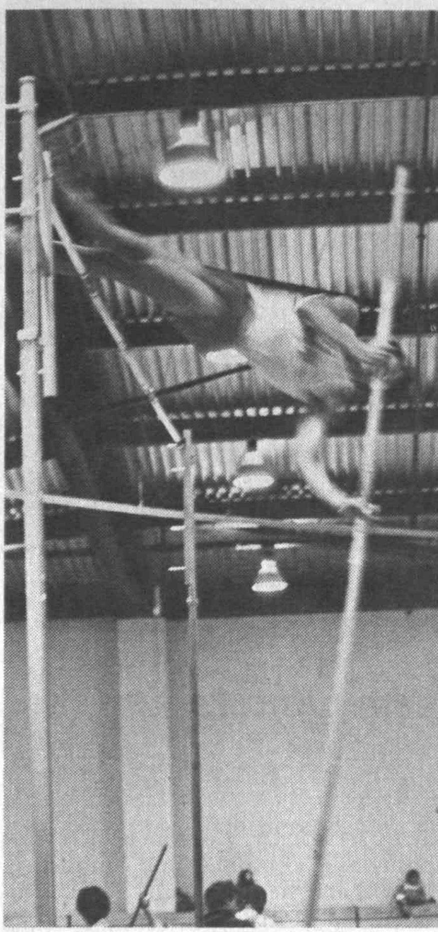
Sixteen members of the wrestling team spent two weeks in Mexico on a training trip "which was very exciting for us," according to Coach Tim Walsh. "We received a tremendous welcome from the Mexicans. They were extremely nice to us."

The Engineers competed in three dual meets against Mexican opponents and finished third among 10 squads in the International Tournament of Lazaro Cardenas on January 14 and 15 in Mexico City. In that tournament, co-captain Ken Shull, '84, and Ed Cashman, '87, finished first in the 150-lb. and 180-lb. weight classes, respectively.

Among the highlights of the trip was a dinner hosted by Raymond Danon, '58, former president of the M.I.T. Club of Mexico. "He was the perfect host, and the athletes had a great time," said Walsh. The wrestlers stayed at the Olympic Village in Mexico City, where other January guests included members of the Hungary and Poland national track squads. They raised money for the trip by selling food at football and in special gifts from alumni wrestlers.

Meanwhile, 27 members ot the M.I.T. men's and women's swimming teams spent two fun-filled weeks on sunny Condado Beach in San Juan, Puerto Rico, on yet another January training trip. In previous years, the swimmers had travelled to Florida during IAP. "Each swimmer paid for his or her own trip," said Coach John Benedick. He calls the visit to Puerto Rico "excellent, our best training trip ever."—*Ken Cerino*

**Above: Men's and women's swimming teams at the Escambron Pool, San Juan.**
**Left: Wrestlers Steve Fernandez, '86, and Ed Cashman, '87 (right), at Tula.**



STEVEN H. WHEATMAN, '86/THE TECH

Pole vaulter Ross Dreyer, '86, clears the bar at 12'0" to win a triangular with Brandeis and Worcester Poly.

## Back for Track, Alumni Lose

They gave it the good old college try, but the alumni lost (again) to the varsity, 79-34, in the 11th annual M.I.T. varsity-alumni track meet late last year.

Though their team lost for the tenth time in this hard-fought series, three alumni won events: Jason Tong, '79, high and triple jumps; Stephen Sifferlen, '78, 35-lb. weight throw; and David R. Wilson, '73, pole vault. For Wilson, it was his 11th consecutive win—meaning every year to date.

Coach Gordon Kelly's varsity squad led by only two points after the field events were completed, but the students pulled away for the easy victory by winning all seven running events. But Coach Kelly is worried: "I hear the alumni are tired of losing, so they're going to try to recruit some more athletes for next year's meeting.

"But we'll be ready," Kelly promises.

Four members of the alumni team came away with second-place finishes—Greg Hunter, '76, shot put; Sumner Brown, '66, 1500-meter run; Bob Collins, '82, 3000-meter run; and Wilson, long jump. Paul Miller, '81, and Pat Hamilton, '81, finished third in the 55-meter dash and 3000-meter run, respectively.

Others competing for the "has-beens" were William A. Friedman, Ph.D.'66 Phys., Charles Anderson, '73, Jaxk Reeves, '77, Rob Gillis, '79, Emerson Yearwood, '79, Chris DeMarco, '80, Tim McManus, '80, Len Nasser, '80, Lew Bender, '81, and Jeff Lukas, '82.

## Fitness Courtesy of '74

Everybody's into it these days—health fitness, that is. And in the cold and snow of winter, fitness becomes an indoor activity for most of its seekers. Hence the popularity of the new Class of 1974 Health Fitness Center in the du Pont Athletic Center—between 12 and 1 and again after 5, you can hardly get in.

The attraction is eight new Nautilus weight-training machines and several new pieces of free-weight equipment, all made possible by gifts of the Class of 1974.

The majority of visitors are students, but faculty and staff members have been using the fitness center on a steady basis as well.

"I like everything about it," says Kathleen McNulty, administrative assistant in the Mechanical Engineering Department. "I use both the Nautilus and free weights. The Nautilus is good for flexibility and toning the muscles. I like the free weights for strength."

Larry Monroe, a graduate student in chemical engineering who is a member of the M.I.T. football team, likes it because "the layout of the equipment is good. There's plenty of room to do a workout."

Charlene Placido, administrative officer in the provost's office, works out three days a week. "This new fitness center is a good supplement for those on sports teams and for those who just want to work out," she says. "From what I can see, everyone who uses the facility is very happy with it."

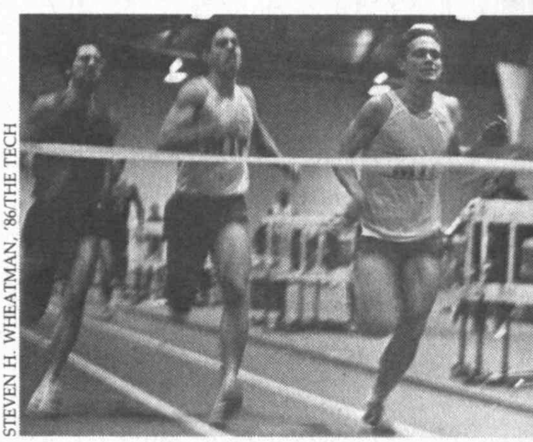
John Terwilliger, freshman heavyweight crew coach who is a fitness center supervisor, usually finds several students waiting when he arrives to open the facility at 8 a.m. "It gets real busy at times," he says, "but we can handle it. Everyone seems to enjoy their workouts."

Gordon Kelly, director of physical education, is also having trouble meeting the demand—"more requests for classes than we can handle. But all that says something about the quality of the fitness center," he concludes.

*—Ken Cerino*

KEN CERINO

John Terwilliger, freshman crew coach who's in charge of the Health Fitness Center, shows how to do it.



STEVEN H. WHEATMAN, '86/THE TECH

Gordon Holterman, '87, breaking the tape at 4:01.5 in the 1500-meter run against Worcester Polytechnic late in the winter.

E.R. Allen

E.U. Buckman

R.N. Cox

M.F. Wagley

# The Selection Committee Reports

## *Three Corporation Nominees, Seven New Officers*

Seven alumni have been chosen by the 1983 National Selection Committee to fill vacancies beginning next July 1 in the leadership of the M.I.T. Alumni Association, according to Joe F. Moore, '52, chairman.

In addition, three alumni have been nominated for term membership on the M.I.T. Corporation:

☐ **Donald J. Atwood,** '48, executive vice-president and director of General Motors Corp.

☐ **Robert L. Mitchell,** S.M.'47 Chem.Eng., vice-chairman and director of Celanese Corp.

☐ **Raymond S. Stata,** '57, president and chairman of Analog Devices.

New Alumni Association officers who will assume their duties on July 1 are:

☐ **Mary Frances Wagley,** '47, executive director of the Episcopal Social Ministries of the Diocese of Maryland, Inc., to be president of the association. Ms. Wagley, whose choice was announced at the National Alumni Conference last September, has been serving (as president-elect) as a member of the Board of Trustees for the current year, and she will also meet with the trustees as past president in 1985-86. Trained as a chemist, Ms. Wagley has taught at Goucher College and Johns Hopkins, and she was for 12 years headmistress of St. Paul's School for Girls in Baltimore. As president of the Alumni Association, she will return next year to membership on the M.I.T. Corporation, of which she was a member from 1970 to 1980; during that decade Ms. Wagley served on no less than nine Corporation committees and visiting committees, including the Executive Committee from 1973 to 1975. She was vice-president of the Alumni Association from 1980 to 1982.

☐ **E. Rudge Allen,** '48, executive vice-president and director of Fayez Sarofim and Co., Houston, to be vice-president of the association. Mr. Allen holds two bachelor's degrees from M.I.T.—in general engineering and chemical engineering; before joining his present company in 1961, he was associated with Exxon Corp. in engineering, economics, and long-range planning. Mr. Allen is a founding life member of the M.I.T. Sustaining Fellows; he's served on many fund-raising committees for the Institute, including those of the Alumni Fund, and he is a member of the Corporation Development Committee.

☐ **Kenneth F. Gordon,** S.M.'60 Mgmt., staff director for research, development, and manufacturing of the President's Commission on Industrial Competitiveness, to be vice-president of the association. His present assignment comes after a long career in government service in the field of technology policy; Dr. Gordon was for five years director of the Planning Office of the National Bureau of Standards, and earlier he was deputy director and assistant director in the Office of Telecommunications (now the National Telecommunications and Information Administration) and special assistant to the Undersecretary of Commerce. Before entering government service Dr. Gordon held several positions in consulting and contract research, and he has taught at the University of Rochester, from which he holds M.A. (1964) and Ph.D. (1967) degrees in economics. He holds the Alumni Association's Bronze Beaver Award (1978) for services to the M.I.T. Club of Washington and as a member of the Association's Board of Directors.

☐ **Russell N. Cox,** '49, president of Resort Management, Inc., Waterville Valley, N.H., to be a director of the association for District 1. Mr. Cox is no stranger to the management of the Alumni Association; he is vice-chairman of the Enterprise Forum, an ex-officio member of the Alumni Council, and chairman of the Alumni Interfraternity Conference; and he received the Bronze Beaver last fall. His professional career has been devoted to real estate development and management, with assignments for Cabot, Cabot, and Forbes, Inc., Linnell and Cox, Inc., and General Investment and Development Co. His M.I.T. degree was in electrical engineering, followed by graduate study at Harvard Business School.

☐ **Christina J. Jansen,** '63, VLSI business manager at Digital Equipment Corp., to be a director of the association for District 2. Ms. Jansen previously held management positions at Millipore Corp., and she is presently responsible for start-up of Digital's first VLSI chip manufacturing facility in Hudson, Mass. She holds three degrees from M.I.T. in materials science and engineering, and

K.F. Gordon

even before completing graduate work (Ph.D.'71) Ms. Jansen took an active interest in alumni affairs as a member of AMITA. She has continued this interest since then and was for three years a member of the M.I.T. Corporation and two of its visiting committees.

☐ **Maria A. Bentel,** '51, partner in Bentel and Bentel, architects, Locust Valley, N.Y., and associate professor of architecture at New York Institute of Technology, to be a director of the association for District 4. Ms. Bentel's work has been honored frequently by the New York State Association of Architects; she holds one gold and six silver ARCHI awards from the Long Island Association of Commerce and Industry; and she is a fellow of the American Institute of Architects, on whose Committee on Design she now serves. Ms. Bentel has been active in the M.I.T. Club of Long Island and the Council for the Arts.

☐ **Ernest U. Buckman,** '46, chairman of Oliver Realty, Inc., Pittsburgh, to be a director of the Alumni Association representing District 5. After graduating from M.I.T. in management, Mr. Buckman held positions in manufacturing and management for ten years before entering the real estate field, and he has been associated with Oliver Realty and its predecessor company since 1959. He's been active as a solicitor for M.I.T. fund-raising programs in the Pittsburgh area, as a member of the Educational Council, as a member of the Advisory Committee on Athletics, and in club and class activities.

**Diana ben Aaron**

*Continued from page A2*

"An Indian elephant," I said.

"An Indian elephant," Lettvin repeated into the mouthpiece. "Fifty-six," he said a moment later. "Thank you, Jim." He hung up.

"Who was that?" I asked.

"Oh, that was my veterinarian," said Lettvin.

"And how did he know that?" I said.

"He also takes care of the animals in the zoo," said Lettvin.

**Seeing the Whole as Well as Its Parts**

Many of the students who drop into the lab discovered it, as I did, when students in Concourse, the "integrated freshman year" program Lettvin founded over ten years ago and has taught in ever since. The professors, teaching assistants, and Cheryl Butters, the administrative assistant who oversees the day-to-day running of Concourse, are frequent visitors. Denice Denton, '81, now a graduate student in electrical engineering, made the smoke-filled salon in Building 20 her first stop when she learned that she would be one of four M.I.T. students featured on a Voice of America program last fall.

Another set of familiar faces belong to students from Bexley Hall, where Jerry and Maggie Lettvin were housemasters for many years and Judah Schwartz, the Concourse physics professor, is housemaster now. "Maggie and I had some of the kids from our years at Bexley out to dinner the other night, and they told us some of the things we *hadn't* known were going on," Lettvin said. "You know that guy who wants a disability pension because he went to two rock concerts? People like that have no idea what it means to *really* put your neck on the line. I am applying to M.I.T. for a disability pension because *I was housemaster of an M.I.T. dormitory.*"

**"Nothing is Better Than Hard Work"**

Some of the other students who frequent the lab come from the courses Lettvin teaches in the regular curriculum. The most popular is 7.51J, General Physiology, the only life-sciences course at M.I.T. based largely on non-destructive, naturalistic observations from zoology. Although modern biology and medicine often take the form of cutting first and asking questions afterwards, Lettvin proves the much can still be learned from the methods of Darwin, Gerald Durrell, and Dr. Doolittle. It is possible to graduate in biology from M.I.T. without working with anything larger than a single cell, but for most research disciplines, a knowledge of physiology—how the whole organism behaves—is a concept that many students learn only from Lettvin.

Grading in General Physiology is based on open-book exams, with the score computed as the absolute value of the number right minus the number wrong. Readers may observe that under this system it would be possible to get an A by answering every question incorrectly. Lettvin knows that, of course, and to doubters he responds, "Our philosophy is, if you get them all wrong—if you are *consistent*—you must know *something*." Once, though, he recalls, "we had a student who never came to class and wrote nothing but derogatory remarks on his exam papers. Him we graded on an imaginary scale."

From time to time, members of the Concourse Computer Center stop by for advice. CCC is a free, student-built, student-operated computer center in Building 20 that has flourished for several years with Lettvin's help in salvaging parts and getting funds; its official name is the Laboratory for Independent Research.

**Photographing a Liberal Education**

The remainder of the company at the lab consists of a variety of passersby—Lettvin's friends seeking stimulating conversation and medical students eager to hear Lettvin's stories about his first love, neurology.

One medical student wants to know about color theory. "Every physicist worth his salt has written a paper on color theory," says Lettvin, taking a drag of his cigarette. "One problem with color theory is that you can make any color look like any other color by the light you shine on it and the colors you surround it with.

"I will give you an example. Do you know the Carravagio picture of Dionysus with grapes? You don't? Well, the grapes are painted using slate blue paint, but in the picture they look green. You go up close and see blue and gray, but from far away they are green grapes. Go and see for yourself, it's in the Borghese Parc in Italy. In fact, you'll have to go to Italy to see it because it has never been photographed. The colors don't look right, the photograph is never even remotedly the same."

Just as a photograph cannot adequately capture a painting, so this essay cannot capture the experience of 20C-007. It is a liberal education in itself. And now, if you will excuse me, I have an urgent appointment to hang around a smoke-filled outer laboratory in a ramshackle building in a corner of Cambridge.

## Alumni Election for the National Selection Committee

Ballots are due by May 14 in the 1984 Alumni Association national election. At stake are four seats (three-year terms) on the National Selection Committee, whose members will choose national officers of the Alumni Association and nominate alumni members (five-year terms) of the MIT Corporation to take office in 1985. The ballot is inserted to the left, and the nominees are listed below. One candidate from each of the four districts is to be elected.

## District 1

**Virginia C. Grammer**
Charlestown, MA
S.B. 1947, Electrical Engineering and Management
S.M. 1977, Educational Technology
Associate Professor of Computer Science
Wentworth Institute of Technology
Boston, MA

Educational Council, 1973-76; Alumni Council, 1978-84; Alumni Fund Telethons, 1978-82; Technology Day Committee, 1979-82; Class of 1947: Secretary 1977-87, 40th Reunion Committee 1982-87, Reunion Committee 1976-77; AMITA: Career Development Conference Planning Committee 1981-84, High School Visiting Program 1981-84, Board of Directors 1981-82, Nominating Committee 1979-82; MIT Second Century Fund: Solicitor 1972-73; Society of Women Engineers: Counselor, Wentworth Student Chapter, 1983-84; author of *Terrapin LOGO Language Tutorial*, 1983.

**David S. Prerau**
Chestnut Hill, MA
Ph.D. 1970, Electrical Engineering
Principal Member of Technical Staff
Computer Science Laboratory
GTE Laboratories, Inc.
Waltham, MA

MIT Club of Boston: Board of Directors 1974-76, Executive Committee 1977—, President 1981 and 1976-77, Vice President 1980, Secretary 1975-76, Chairman of the West Suburban Regional Board 1982—; Alumni Council, 1980—; Member: Sigma Xi; Tau Beta Pi; Eta Kappa Nu; IEEE; ACM; American Association for Artificial Intelligence; Awards: American Federation of Information Processing Societies Award.

**Please fill out the ballot at the left and return it promptly. Polls close on May 14.**

## District 5

**Joseph V. Iemolo**
Haverford, PA
S.M. 1962, Management
Manager—Scientific Marketing
Sperry Corporation
Blue Bell, PA

Alumni Fund PST Telethon, 1981-82; 1982 Philadelphia AOC Coordinator; Member, Sloan School Graduate Association; MIT Club of Delaware Valley: President 1980-82, Vice President 1978-80, Executive Committee Member 1972-83, Secretary 1974-75; Member: Greater Philadelphia Chamber of Commerce, Boy Scouts of America, National Conference on Scientific Computing; Awards: President's Award of the Greater Philadelphia Chamber of Commerce.

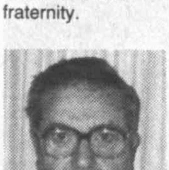
**Kenneth F. Gordon**
Bethesda, MD
S.M. 1960, Management
Staff Director
President's Commission on Industrial Competitiveness
Washington, DC

Alumni Association: Vice President 1984-86, Director 1976-78, Awards Committee 1979-82; Alumni Fund: Personal Solicitation Vice Chairman 1983-84, Solicitor 1982-84, Chairman 1978-79; Telethon (Washington DC) 4 years, Regional Gifts Chairman 1977-88; MIT Club of Washington: President 1974-75, Vice President 1972-74, Board of Directors 1972-84, Seminar Series Program Chairman 1982-83, Science Policy Symposium Chairman 1976; Member: AAAS, World Future Society, Senior Executives Association; Awards: Alumni Association Bronze Beaver, 1978.

## District 6

**Paul H. Fricke**
Arlington Heights, IL
S.B., 1961, Chemical Engineering
Vice President, Investment Management Division
The Illinois Company, Inc.
Chicago, IL

Alumni Fund: Area Council, District Chairman, Solicitor, Telethon; Alumni Association Activities Board 1979-81; Educational Council 1969-84; MIT Enterprise Forum: Co-Chairman 1983-84; MIT Club of Chicago: Director 1978-84, President 1977 (Regional Management Conference and Presidential Citation), Officer 1969-76; Member: Investment Analysts Society of Chicago (Education Committee, 1973-76), Financial Analysts Federation, Institute of Chartered Financial Analysts, Delta Tau Delta fraternity.



**L. Walter Helmreich**
Ann Arbor, MI
S.B. 1940, Electrical Engineering
Electrical Engineer and Consultant (Retired)

Educational Council: Member 1966-84; Vice Chairman Ann Arbor Area 1973-84; Member: HKN, Scout/Scouter Boy Scouts of America 1929—, Beta Theta Pi; Awards: Alumni Association Morgan Award 1979.

## District 7

**Parke D. Appel**
Venice, FL
S.B. 1922, Electrical Engineering
New England Telephone Co.
Retired 1964

Alumni Fund Board, 1965-66; Alumni Council: Member 1945-77, Life Member 1977—; Alumni Day Committee, Chairman 1947; MIT Club of Southwest Florida: Director 1973—, President 1977—; MIT Florida Festival: Originator 1976, Coordinator for Sarasota Area 1981; Class of 1922: President 1934—, Reunion Chairman 1939-82, 50th Reunion Gifts Chairman 1968-72, Regional Gifts Chairman for Sarasota 1957—; MIT Second Century Fund Co-Chairman for Boston, 1961-63; Member: Tau Beta Pi 1922—, Veno Chapter Telephone Pioneers (President 1977—). Alumni Association Bronze Beaver Award 1964.

**Leo H. Dee**
**Boynton Beach, FL**
S.B. 1935, Electrical Engineering
General Electric Co., Retired
Lt. Cmdr. USNR, ret.

Alumni Fund: Solicitor for annual and reunion gift drives. MIT Club of Palm Beach County: President 1981-82, Vice President for Programs 1980-81, Secretary/Treasurer 1979-80, Advisory Board 1982-84; Class of 1935 Reunion Committee, Member for 45th and 50th Reunions; Member: MIT Club of Cape Cod, Citizen Committees on Schools and Town Development Planning, IEEE (Life Member).

**Cyril W. Draffin, Jr.**
Washington, DC
S.B. 1972, S.M. 1973, Chemical Engineering
Vice President
Greater Washington Investors, Inc.
Washington, DC

MIT Educational Council, 1974-83; MIT Club of Washington DC: President 1980-81, Vice President 1979-80, Treasurer 1977-78, Workshop Chairman 1981, Director 1978-84, Seminar Series Committee 1982-83, Outstanding Service Award 1983; MIT Enterprise Forum of Washington. Vice-chairman 1982-84; MIT Club of Southern California 1973-75; MIT Glee Club, President 1971-72; Member: Phi Lambda Upsilon, Phi Delta Theta Fraternity, Washington Society of Investment Analysts, Washington Management and Business Association (Director 1981-84), Washington Entrepreneurship Institute.

**Donald Elon Robinson**
St. Petersburg, FL
S.B. 1946, Aeronautical Engineering
Executive Vice President
RO-MO Color Lab, Inc.
St. Petersburg, FL

Educational Council 1972—; MIT Club of Tampa Bay: President 1975-77, Secretary 1978—; Member: St. Petersburg Chamber of Commerce (Baseball Committee 1978-83), Police Athletic League, (Director 1965—, President 1968-69), Suncoast Chamber of Commerce, Better Business Bureau (Chairman, Arbitration Committee), Goodwill Industries (Director 1975-81, Vice Chairman 1981); Rotary International (Chairman Information Committee 1983); Sun Bay Community Hospital Board of Directors 1978-81; St. Petersburg Catholic School Board Long Range Planning Committee 1978-80; Boy Scouts of America Scoutmaster 1966-80; Award: Alumni Association Lobdell Award, 1980.

# Courses

# I
## Civil Engineering

**Peter S. Eagleson,** Sc.D.'56, who was head of the department at M.I.T. from 1970 to 1975, is now the Edmund K. Turner Professor of Civil Engineering. The chair was endowed in 1969 to honor the memory of one of M.I.T.'s first civil engineering graduates (Class of 1870) and first held by Professor Emeritus **T. William Lambe,** Sc.D.'48. Eagleson joined the faculty before completing his doctorate, and his work in hydrology has been widely honored by ASCE and the American Geophysical Union.

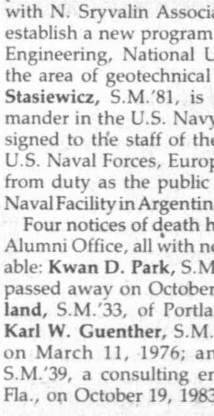
Professor **Steven R. Lerman, '72,** has a big new job: he is head of Project Athena, the $50 million program to provide a new, coherent computer system to support educational programs throughout M.I.T. He'll be responsible to the Athena executive committee for meeting the project's ambitious goals, which are based on a network of 2,500 to 3,000 advanced personal computers to be installed throughout the campus during the next five years. Lerman has been a member of the faculty since 1975, and he now heads the department's Transportation Systems Division in which he wrote his Ph.D. thesis.

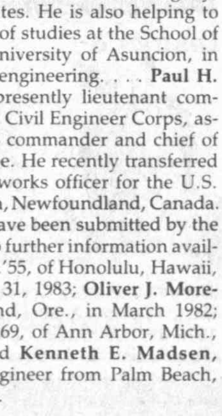
**S. Bruce Smart, Jr.,** S.M.'47, chairman and chief executive officer of The Continental Group, Stamford, Conn., was campaign chairman for the United Way of Tri-States 1983 fund-raising campaign. He headed 100 leadership and nearly 150,000 workplace volunteers in New York, New Jersey and Connecticut. . . . **Joel R. Alper,** S.M.'59, executive vice-president of Communications Satellite Corp. (COMSAT), Washington, D.C., was elected (in November 1983) president of COMSAT World Systems Division, the company's largest business. . . . **Ru-Liang (Leon) Wang,** Sc.D.'65, professor of civil engineering at the University of Oklahoma, Norman, coordinated a joint AIT-CCNAA (American Institute in Taiwan-Coordination Council on North American Affairs) seminar on "Research for Multiple Hazard Mitigation" at the National Cheng-Kung University, Tainan, this past January. The seminar was sponsored by the National Science Foundation and the National Science Council in Taiwan. The delegation consisted of ten experts in earthquake engineering, wind engineering, flooding, landslides, etc., from many parts of the United States. On his way to Taiwan, Wang also visited Toyohashi University to discuss a possibility of a joint U.S.-Japan seminar on lifeline earthquake engineering.

**Norman R. Rosen,** S.M.'54, has been president of Epstein and Sons, Inc., Engineers and Architects, Chicago, Ill., since November 1983. . . . **Willard E. Simpson, Jr.,** '40, writes, "I am still active in the engineering business and profession as president of W.E. Simpson Co., Inc., Consulting Engineers (civil/structural), practicing in central and south Texas, out of San Antonio. I intend to continue as long as I can remain productive. I am blessed with an organization—a kind of family of associates—composed of a few older, but mostly younger, men and women who are continuing the record of company achievement started in 1909 by my father, the late W.E. Simpson, '05. This is not to deny that after 43 busy years which includes service to God, country, community, and charities that I find more and more pleasure in outdoor recreation, including hunting and fishing, and yes, social affairs with my wife Betsy. Oh, yes, this includes continuing interest in the lives and careers of our three (adult) children and their families."

**Antonio A. Gonzalez Quevedo,** S.M.'77, writes, "I am currently lecturing at the University of Puerto Rico, Mayaguez. I teach a course on mechanics and another on mechanics of materials for the General Engineering Department. The department provides support to all the engineering departments by developing and teaching the basic courses in engineering." . . . **Sue Finkelstein,** S.M.'64, is author of *OS JCL and Utilities: A Comprehensive Treatment, recently published by Addison-Wesley*. . . . **Eva Lerner-Lam,** S.M.'78, is currently director of planning and operations for the San Diego Metropolitan Transit Development Board, involved in the develoment of San Diego trolley extensions and the coordination of multiple operator bus transit systems. . . . **Stanley M. White,** S.M.'76, is currently president of Ocean and Coastal Consultants, Inc., Westport, Conn. . . . **M. Stanichevsky Sryvalin,** S.M.'83, is currently working as project manager for the expansion of the Excelsior Hotel, Asuncion, Paraguay, with N. Sryvalin Associates. He is also helping to establish a new program of studies at the School of Engineering, National University of Asuncion, in the area of geotechnical engineering. . . . **Paul H. Stasiewicz,** S.M.'81, is presently lieutenant commander in the U.S. Navy Civil Engineer Corps, assigned to the staff of the commander and chief of U.S. Naval Forces, Europe. He recently transferred from duty as the public works officer for the U.S. Naval Facility in Argentina, Newfoundland, Canada.

Four notices of death have been submitted by the Alumni Office, all with no further information available: **Kwan D. Park,** S.M.'55, of Honolulu, Hawaii, passed away on October 31, 1983; **Oliver J. Moreland,** S.M.'33, of Portland, Ore., in March 1982; **Karl W. Guenther,** S.M.'69, of Ann Arbor, Mich., on March 11, 1976; and **Kenneth E. Madsen,** S.M.'39, a consulting engineer from Palm Beach, Fla., on October 19, 1983.


**S. B. Smart**


**J. R. Alper**

# II
## Mechanical Engineering

Four groups of graduate students working with Professor **Warren P. Seering** submitted successful entries in the 1983 Student Engineering Design Competition of the James F. Lincoln Arc Welding Foundation. Merit awards were given to **Louis G. Tarricone, Hari Das, Michael Cane,** and **Michael Kelly,** S.M.'83, for "An Automated Test Fixture Fabrication System Using a Three-Axis Cartesian Robot"; to **Akim Lennhoff, Steven Judson, Sam Landsberger,** and **David Serrano** for "A Roller-Bearing Hone"; to **Brian Jacobs,** '83, **Thanasis Molokotos, Bill Townsend,** and **Robert Chave** for "A Film-Testing Machine"; and to **Neil Singer,** '83, **Hugh Costello, Gontran Kenwood,** '82, and **Marie-Louise Murville,** '82, for "Design of a Programmable Parts Feeder."

**Richard Parmelee,** Ph.D.'66, a member of the Operating System Technology Group in the IBM Cambridge Scientific Center, is now associate director of Project Athena, representing IBM in the management of this major effort to bring "coherent" computer programs to educational activities throughout M.I.T. Parmelee was associated with the department's computer-aided design project when he received his Ph.D., and he has been with IBM since the early 1970s.

The Francis J. Clamer Medal of the Franklin Institute of Philadelphia was given late last year to **Louis F. Coffin,** Sc.D.'49, of the General Electric Research and Development Center's Metallurgy Laboratory. The silver medal is "for meritorious achievement in the field of metallurgy"; Coffin was cited for "classic contributions to knowledge concerning the fatigue of metals."

**John E. Jones,** S.M.'57, reports that since June 1981 he has been director of engineering at Singer Motor Products Divsion; he moved to Greenville, S.C., in July 1981; and he adds that he had an enjoyable visit to M.I.T., Boston, and Quincy Market last summer. . . . **S.J. Kline,** Sc.D.'52, is currently professor of mechanical engineering and of values, technology, science and society at Stanford University. He was elected to the National Academy of Engineering in 1981. . . . **Jerry R. Wood,** S.M.'69, writes, "Previously, I was head of the Centrifugal Compressor Section at the NASA Lewis Research Center. Currently, I am head of the Design and Analysis Section of the Fan and Compressor Branch at Lewis." . . . **Chester A. Siver,** S.M.'35, is chairman and chief executive officer of Conval, Inc., Somers, Conn., manufacturing and marketing a line of forged steel valves for the chemical, utility, paper, and oil industries. The valves are for high-temperature, high-pressure service and are made of various metals, some standard and others exotic. Siver designed the line of valves, holds many patents, organized the corporation and manufacturing facility, and runs it.

**James Fleischhacker,** S.M.'68, has been promoted to division manager of the Components and Assemblies Division of AMP, Inc., which has manufacturing in Florida and North and South Carolina.

. . . **Carl C. Heller,** S.M.'74, writes, "I now work for the Electric Power Research Institute, Palo Alto, Calif., as project manager heat pump applications." . . . **David S. Brookstein,** S.M.'73, is currently assistant director at Albany International Research Co., Dedham, Mass. . . . **Hendrik Ter Maat,** S.M.'72, writes, "My new position is operations manager with Hoogovens Automation Systems (H.A.S.), Amsterdam, The Netherlands. H.A.S. is a systems house for flexible production automation. The main topics at the moment are the use of robots, flexible manufacturing systems, and computer integrated manufacturing (CIM), and its introduction in European industry." . . . . **Susan C. Swindler,** S.M.'80, is presently a quality engineer for NYNEX, Inc. . . . **Michael A. Feldstein,** S.M.'66, writes, "I have recently returned from 'Silicon Valley,' Calif., to the greater Boston area and established a technical consulting practice, specializing in computer disk and tape memories."

**John V. Solomon,** S.M.'62, reports that he continues to be very active in local and regional youth soccer and is a licensed soccer referee. His middle son, Matt, is now a freshman at M.I.T. and participates in varsity soccer. . . . **Norman R. Lampert,** S.M.'79, has returned to Bell Laboratories, Atlanta, Ga., working in fiber optics and received a patent on a microwave stripline support assembly. Also, his second son, Travis Mitchell, was born on September 6, 1983. . . . **Avram Bar-Cohen,** Ph.D.'71, associate professor of mechanical engineering at Ben-Gurion University of the Negev, Israel, has been recognized for his work in the analysis and design of thermal control systems for electronic equipment, as a fellow of the American Society of Mechanical Engineers. . . . **Robert H. Cannon, Jr.,** Charles Lee Powell Professor and Chairman of the Department of Aeronautics and Astronautics at Stanford University, Calif., has been elected a member to the Corporation of the Charles Stark Draper Laboratory, Inc., Cambridge.

**Frederick C. Muller,** '46, instructor at Prince Georges Community College, Largo, Md., passed away on March 24, 1983. . . . **William Ward Powell, Jr.,** S.M.'46, of Charlotte, N.C., passed away on December 7, 1981; no details are available. . . . **John L. Nolte,** S.M.'65, assistant staff engineering at Chevrolet Engineering Center, Warren, Mich., passed away suddenly of a heart attack on August 12, 1983.

# III

## Materials Science and Engineering

**McDonald Robinson,** Sc.D.'67, has joined (November 1, 1983) Epsilon Technology, Inc. (ETI), as manager of process development. ETI is a recently formed subsidiary of Advanced Semiconductor Materials of America. Prior to this position Robinson (for 14 1/2 years) was at Bell Laboratories, Murray Hill, N.J., where he received a Distinguished Technical Staff Award for "sustained individual technical performance." . . . **Jerry Turnbaugh,** Sc.D.'62, manager of Safety Services at Tektronix, Inc., Portland, Ore., has been reappointed to the State (Oregon) Advisory Council on Occupational Safety and Health. . . . **Firoze E. Katrak,** Sc.D.'79, is currently vice-president of the Natural Resources Group at Charles River Associates, Inc., Boston. . . . **Howard R. Spendelow, Jr.,** Sc.D.'42, retired as president on March 1, 1983, of Shieldalloy Corp. but remains a director and consultant to the company. . . . **Philip H. Smith,** '52, is active in Hartley Smith, Partners, specializing in portfolio management and turnaround companies, headquartered in Pittsburgh, Penn. . . . **Dennis W. Readey,** Sc.D.'62, has been chairman of the Departmant of Ceramic Engineering at Ohio State University since July 1982. . . . **Robert C. Ruhl,** Ph.D.'67, is currently director of manufacturing engineering for Sohio Chemicals and Industrial Products Co., Solon, Ohio. . . . **Thomas R. Clevenger,** Sc.D.'61, writes, "I recently went into business for myself, setting up a consulting firm here in Tokyo. At present, the firm represents two U.S. companies who have no office in Japan but do have investments. Also, I am acting as an advisor to two other U.S. companies. Hopefully, my 22 years of experience in the Far East, working on technical and business matters, will provide a good background for a prosperous venture."

**Robert D. MacDonald,** S.M.'40, reports that he is a retired consultant. . . . **Albert E. Paladino, Jr.,** Sc.D.'62, joined Advanced Technology Ventures as a general partner in December 1981. The firm is a venture capital group making investments in early-stage, high-technology companies. . . . **William M. Shakespeare,** '42, is the principal of Shakespeare Ceramics Consulting, Boston, with clients in Great Britain, Ireland, France and the United States. The firm focuses on "concepts for ceramic materials and processes, and the bringing together of needs and sources." Shakespeare has initiated developments in the field, such as precision forming of ceramics by casting, pressing, iso-static pressing; and ceramics with tailored electrical, mechanical, and thermal properties.

**John A. Crichton,** S.M.'38, writes, "I am chairman of Arabian Shield Development Co., which is in the process of building a mill and reactivating a gold, silver, copper, and zinc mine in Saudi Arabia, that was worked at a shallow level by the Queen of Sheba." . . . **Paul H. Adler,** S.M.'81, is presently a metallurgist at Lawrence Livermore National Laboratory.

The following notices of death have been submitted by the Alumni Association, with no further details available: **John C. Lewis, Jr.,** '35, of Tacoma, Wash., passed away on November 23, 1983; **Jeremiah P. O'Connor,** '35, of Revere, Mass., on June 4, 1976; **Richard F. Miller,** Sc.D.'34, of Winter Park, Fla., on February 2, 1983; **Franklyn D. Owen, Jr.,** '52, president of Owen Steel Co., Columbia, S.C., in March 1982; and **John C. Nicholls,** S.M.'51, of Alburg, Vt., on May 9, 1981.

# IV

## Architecture

**Robert L. Ziegelman,** M.Arch.'59, reports that he was bestowed the Michigan Society of Architects 1982 Award of Honor for the Handleman Distribution Center in Chicago, and for the Medallion Professional Office Building in Farmington Hills. He is currently working on converting waterfront warehouses on Staten Island, N.Y., to condominiums and developing the former estate of Meri-Weather Post in Washington, D.C., into 120 attached townhouses. . . . **Maurice F. Childs,** M.Arch.'60, is currently principal of Childs Bertman Tseckares and Casendino, Boston, architects, landscape architects, and urban designers. He is also a member of the visiting committee of the School of Architecture and Planning at M.I.T. . . . **William W. Caudill,** M.Arch.'47, an Oklahoma State University alumnus and an internationally respected architect, author and educator, who passed away on June 25, 1983, has been inducted posthumously into Oklahoma's Hall of Fame. At the reception banquet, Caudill was called "one of many people who helped to make Oklahoma." He was the recipient of several honorary degrees, his firm won more than 300 awards for design excellence and innovation, and he pioneered the concept of "architecture by team" for professional practice.

**James A. Carr,** M.Arch.'72, reports that he is presently a partner in the architectural firm of J. Gordon Carr and Associates, New York City, and his first child, James Gordon Carr, was born on December 1, 1983. . . . **Robert S. Allan,** M.Arch.'55, writes, "We have continued to expand our two firms, Robert S. Allan, Architects, Engineers, Planners, Inc., and R.S. Allan, Management Consultants. In particular we are attempting to expand our operations into development of office and recreational type facilities. Also managed to spend a number of weekends last year sailing." . . . **John Sullivan, Jr.,** M.Arch.'38, reports, "Have traveled extensively since my wife died in 1982. Took my two daughters to New Zealand and Australia last February and March. Spent the summer traveling 10,000 miles—east then west, through the U.S. and Canada, painting water colors along the way. Finished a show in November 1983, and sold ten paintings."

**Hans-Christian Lischewski,** M.Arch.'79, recently joined SOTA Associates, Inc., Greenwich, Conn., as a director of research and development to develop and set up high tech design and production services for the architectural engineering industry on a national basis.

**Doru Iliesiu,** M.Arch.'83, writes, "The search for research and development funds started to receive some encouraging signs recently. The construction industry is very slow in Toronto, Canada, particularly for a free-lance."

**Francis Sellew,** M.Arch.'35, a retired architect and partner in the Quincy, Mass., firm of Sellew, Doherty and Shesky, passed away on November 23, 1983. He was a former president of the Boston Architectural Society and member of the American Institute of Architects, and under his leadership his firm served several schools in Eastern Massachusetts.

# V

## Chemistry

**William T. Lindsay,** Ph.D.'52, has recently retired after 30 years with Westinghouse Electric Corp. and is now living in Hopkinton, Mass. Presently he is consulting for the electric power industry. . . . **J. Throck Watson,** Ph.D.'65, is presently professor of biochemistry and chemistry at Michigan State University, where he is also director of the mass spectrometry facility.

**Richard P. English,** Ph.D.'70, is currently director of product assurance at Applied Materials, Inc., Santa Clara, Calif. . . . **Kofi Bimpong-Bota,** Ph.D.'75, writes, "I have been acting president of the Atlanta University since July 1, 1983." . . . **Donald M. Black,** Ph.D.'47, has been appointed manager of regulatory compliance for McKesson Chemical Co.

**George T. Weed,** S.M.'32, writes, "After retirement (December 1976) from DuPont Far East (Japan), Inc., I went to Richmond, Surrey, England, to be near my daughter and grandchildren who were then residents of Hague, Holland. Since early 1980, we (with my wife, Marie) have re-established our residence in Honolulu. We swim in the lagoon and jog in Ala Moana Park. I do some voluntary work for the Kuakini Hospital and the Department of Education. I still find time for a little golf, photography, and reading."

**Raisa (Berlin) Deber,** Ph.D.'77, and **Charles M. Deber,** Ph.D.'67, are both associate professors at the University of Toronto (Raisa: the Department of Health Administration, and Charles: the Department of Biochemistry). They have a son, Jonathan Arthur, born in 1981. Raisa has recently hosted the Toronto meeting of the Society for Medical Decision-Making. Charles researches the properties of peptides and proteins interacting with membranes. On the "side," he constructs crossword puzzles, several which have appeared in the Sunday *New York Times Magazine*.

**Albert A. Fournier, Jr.,** Ph.D.'57, writes, "I have joined the American Tape Co. as vice-president of research and development." . . . **William W. Schloman, Jr.,** Ph.D.'71, formerly a chemist at Goodyear, has been named senior research scientist at Firestone Tire and Rubber Co.'s Central Research Laboratories, Akron, Ohio. . . . **Alan L. Smith,** Ph.D.'65, writes, "I am presently an associate professor of chemistry at Drexel University, Philadelphia, Penn. Last fall, I chaired the faculty committee that selected the microcomputer that all of our freshmen are required to purchase and am now coordinating the faculty development effort we are making to prepare for using these computers across our undergraduate curriculum."

**Carlos L. Vila,** Ph.D.'78, has joined the Chemistry Department at West Chester University, Penn., teaching analytical chemistry and doing research in HPLC and GC. . . . **Paul D. Jeffrey,**

S.M.'77, is expected to graduate in February 1984 with a Master's in business administration with a concentration in marketing and international business from New York University. In December 1983, he accepted a position with Pfizer Pharmaceuticals, New York City, as a strategic planning analyst.

# VI

## Electrical Engineering and Computer Science

Three members of the M.I.T. community are among Boston-area IEEE members awarded the grade of fellow: **Dimitri P. Bertsekas,** Ph.D.'71, professor of electrical engineering at M.I.T.; **Erich P. Ippen,** '62, professor of electrical engineering at M.I.T.; and **John G. Proakis,** S.M.'61, professor of electrical engineering at Northeastern University.

**John M. Fluke,** S.M.'36, former chairman and chief executive officer of John Fluke Manufacturing Co., Everett, Mass., has become the firm's chairman. . . . **Henry Reinecke, Jr.,** S.M.'60, former vice-president and general manager of Wavetek Corp., San Diego, Calif., has become group vice-president of the general purpose products division. . . . **John Brennand,** S.M.'59, and his family of Santa Barbara, Calif., were honored as the Family Service Agency's first annual Family of the Year. The designation was based on "the family's community service, teamwork, and fostering of individual growth." Among a few of the organizations the family is involved in are: the Girl Scouts, Boy Scouts, 4-H, Hillside House, Jaycees, National Charity League, and the Children's Home Society. . . . **Albert A. Mullin,** S.M.'57, has published a technical paper on M.I.T.'s version of public-key cryptosystems (R.S.A.) in the international journal *Computers and Security.* . . . **Wilbur L. Pritchard,** '52, is currently president of the Direct Broadcast Satellite Corp.

**Douglas R. Cobb,** S.M.'65, became vice-president/operations manager of the Audichron Co., Atlanta, Ga., in July 1983. . . . **Jeffrey A. Kaplan,** S.M.'71, has completed his first year as manager of electric power systems programming for Leeds and Northrup Co., North Wales, Penn. . . . **Donald G. O'Brien,** S.M.'51, has been elected to the Board of Directors of the University of New Hampshire Alumni Association (for a three-year term); he's also serving on the Board of Directors of the American Association of Industrial Management of New England, Inc. . . . **Thomas M. Jahns,** Ph.D.'78, a former research engineer for Gould, Inc., Rolling Meadows, Ill., has recently joined the General Electric Research and Development Center, Schenectady, N.Y., as an electrical engineer.

**Ronald D. Haggarty,** S.M.'61, associate head and group leader of the Signal Processing and Electronic Warfare Department at the Mitre Corp., Bedford, Mass., has been promoted to chief engineer of Bedford operations, responsible for developing technology programs, reviewing proposals for research and development, monitoring ongoing programs, and strengthening quality control. And **Edward A. Palo,** S.M.'65, group leader of radar technology, has been promoted to replace Haggarty as head of the Signal Processing and Electronic Warfare Department.

**Edward D. Ostroff,** '51, joined the Mitre Corp. in June 1983, after 17 years at Raytheon. . . . **Dean Vanderbilt,** Ph.D.'70, writes, "I am currently a division manager with Fox and Jacobs, Inc., a Dallas-based homebuilding company. In April 1983 I was elected a member of the Dallas City Council. My wife Missy is a broker with Ebby Haddiay, the largest residential real estate brokerage firm in Dallas. We have two children: Reed (14) and Holly (11)."

The Alumni Association has been notified of six deaths, with no further information available: **Paul J. Johnson,** '33; of Roanoke, Va., passed away on July 12, 1983; **Gerald R. Rogers,** S.M.'61, of Fort Walton Beach, Fla., on January 16, 1975; **Renato N. Nicola,** '53, Manager of Kaman Aircraft Corp., Bloomfield, Conn., on June 13, 1978; **Frederick W. Baumann,** S.M.'34; of Scotia, N.Y., on July 17, 1978; **Gustave A. Nylander,** '52, of Mount Holly, N.J., on September 2, 1981; and **William P. Douglass,** S.M.'35, of Cypress, Calif., on July 3, 1983.

R. D. Haggarty

## VI-A Program

ROLM Corp. has joined the VI-A Program and will have its first students working this summer in their Office Systems Division in Santa Clara, Calif. ROLM is well known for its integrated computer and communications systems and for the manufacture of military-specification computers. A number of M.I.T. alumni are currently employed there, and James Cochrum, who will act as VI-A technical coordinator, helped establish VI-A at Hewlett-Packard's Computer Division when formerly employed at H-P. Professor Carl E. Hewitt, who has consulted for ROLM, will be their first VI-A faculty adviser.

Analog Devices, Inc. will add assignments this summer at its Measurement and Control Division (MCD) in Norwood, Mass. The company was founded in 1965 by **Raymond S. Stata,** '57, himself a VI-A graduate. Its first VI-A students were assigned to Analog Devices Semiconductor Division (ADS), Wilmington, Mass., in the summer of 1982. Adding positions at MCD was originally contemplated if the initial assignments at ADS worked out well. Under the guidance of Analog's VI-A faculty adviser, Professor L. Rafael Reif, students have done well at ADS.

All signs point to this being another year of great pressure on the VI-A Program, which is now burdened with a total spring enrollment of 290 students. Recent counts indicate the Spring-Term sophomore enrollment in Course VI is up to 400. Should the same proportion of students (63.4 percent) apply for admission to VI-A this year as last, that will mean 255 applications, compared to last year's 66-year peak of 254. All this comes at a time when the department feels that, because of pressure on its present faculty, it must limit the program to about 250.

These pressures also come at a time of industrial resurgence in many of our co-operating companies who are pleading to take more VI-A students. Last year 109 were admitted to the Program in anticipation of a total summer enrollment of 262. As noted above, this didn't quite work out and we are now at 290. Of course, this means a cutback in this year's admissions that will be hard on both students and companies. And, incidentally, there are still some 110 companies currently expressing interest in joining the Program!

As this year ended, we were honored to receive greetings from a number of VI-A alumni including: **Geoffrey J. Bunza,** '74; **John F. Cooper,** '74; **David W. Duehren,** '80; **Imre Gaal, Jr.,** '83; **Edward C. Giaimo,** '74; **Bradford E. Hampson,** '75; **Michael A. Isnardi,** '82; **Grace Lee,** '82; **Gary K. Montress,** '69; **Louis A. Nagode,** '80; **Kenneth A. Parulski,** '79; **Sharam Shirazi,** '76; **John G. Strang,** '83; and **Vincent H. Tobkin,** '73. Professor **Truman S. Gray,** '29, and John Tucker each received a long letter from **Michael Moncavage,** '82, written in Schlumberger's company compound in Hofuf, Saudi Arabia, where Mike is now serving as a field engineer. His letter gives an extremely interesting and detailed description of his work in seismic oil exploration in that section of the world. Professor Gray is VI-A faculty adviser to TI/Houston, where Mike did his VI-A work, and also served as Mike's thesis supervisor.

Incidentally, **Vince Tobkin,** '73, came by the VI-A Office for a short visit on January 27. He has become a principal partner in McKinsey and Co. of San Francisco, Calif., and travels extensively.

In mid-January John Tucker made a quick VI-A trip to the San Francisco Bay area, primarily for a luncheon ceremony at ROLM Corp. for the signing of the new VI-A contract and to discuss spring selection activities with the Hewlett-Packard Co. and Xerox's Palo Alto Research Center. During the course of that visit contact was held with a surprising number of Course VI and VI-A graduates: at ROLM Corp., **Peter Bonee,** '79; at Hewlett-Packard Labs., **Ira P. Goldstein,** '74, **Paul E. Stoft,** '49, and **Kenneth A. Van Bree,** '71. At the Palo Alto Holiday Inn coffee shop, one morning, a voice said, "Won't you join us for breakfast?" It was **Roger W. Sudbury,** '63, of Lincoln Laboratory on a business trip with several guests from the Raytheon Co. An evening's dinner was arranged with **J. Dana Chisholm,** '75, from San Jose, and **Robert M. Colopy,** '74, of Palo Alto, both of whom are currently running their own consulting businesses. Another evening meeting was arranged with **J. Payne Freret, Jr.,** '68, and his wife **Lynn M. Roylance,** '72, and **Allen J. Baum,** '73. Allen has moved from H-P Labs. to a new firm in Menlo Park, Calif., called Integrated Switching Systems, Inc. **John F. Cooper,** '74, joined Tucker for a day's trip, on the weekend, to the lovely coastal area around Half Moon Bay, Calif.

Quoted in *Electronics* is **Steven L. Bates,** '74, from his paper delivered at the fall meeting of the International Test Conference (the so-called "Cherry Hill Test Conference"). Steve is with GenRad, Inc., Concord, Mass. In the same October 6, 1983, issue is an article on **S. Dana Seccombe,** '70, and his VLSI work at H-P.

Other recent visitors to the VI-A Office, not already mentioned, include: **Kenneth R. Knaus,** '78, with Hewlett-Packard, Palo Alto, Calif.; **Steven K. Ladd,** '81, with Megatest, Inc., Palo Alto, Calif.; **Jack E. Link,** '83, H-P Medical, Waltham, Mass.; **David Raitzin,** '83, with Intel Corp., Phoenix, Ariz., and **George B. Yundt,** '80, who is now with IMEC Corp. in Boston, Mass.—John A. Tucker, Director, VI-A Program, M.I.T., Room 38-473, Cambridge, MA 02139

# VII

## Biology

**Thomas Berman,** Ph.D.'64, is a research professor in aquatic microbiology, working on primary productivity and microbial nutrient cycling in Lake Kennert (Sea of Galilee), the Don River, and the Eastern Mediterranean. . . . **Nancy E. Kleckner,** Ph.D.'74, a genetic researcher in the Biochemistry and Molecular Biology Department at Harvard, has recently become the University's 19th tenured female professor. "In our search we looked both inside and outside the University for the person most qualified to fill the position . . . we picked Nancy Kleckner for her contributions to her field, her research, and her teaching," said Department Chairman James C. Wang. Kleckner has been identified as a leader in the field of bacterial transponsens and has been praised for her contributions in the field of genetics. . . . **Emanuel L. Goldman,** Ph.D.'72, was promoted to associate professor of microbiology with tenure at the New Jersey Medical School, Newark, on July 1, 1983. Since then he's received a Research Career Development Award from the National Cancer Institute.

# VIII

## Physics

**Herbert B. Callen,** Ph.D.'47, professor of physics at the University of Pennsylvania, was honored late last year with the Elliott Cresson Medal of the Franklin Institute of Philadelphia. The medal is for "original research adding to the sum of human

knowledge," and Callen was cited for his contributions to understanding macroscopic processes in materials. The impact of Dr. Callen's work, said the Franklin Institute, lies in "the development of calculation methods to understand electrical processes in systems such as semi-conductors . . ."

**W. Murray Bullis,** Ph.D.'56, writes, "This fall I assumed the position of Director of Technology of the Silicon Division at Siltec Corp., Mountain View, Calif." . . . **Daniel E. Murnick,** Ph.D.'66, of Bell Telephone Laboratories, New Providence, N.J., has received the Humboldt Prize for Excellence in Research from the Federal Republic of Germany. . . . **Nelson L. Alpert,** Ph.D.'48, of Stamford, Conn., has been appointed to the Expert Panel on Instrumentation of the International Federation of Clinical Chemistry and attended the meeting last July in Budapest. . . . **Solomon J. Buchsbaum,** Ph.D.'57, executive vice-president of customer systems at Bell Laboratories, Holmdel, N.J., has been elected a member of the Corporation at the Charles Stark Draper Laboratory, Cambridge.

**Eugene I. Gordon,** Ph.D.'57, writes, "Just took early retirement from Bell Laboratories. Presently doing independent consulting, as I complete plans to establish my own company to manufacture semiconductor devices for fiber optic communications." . . . **Margaret H. Weiler,** Ph.D.'77, reports, "After six years in the Physics Department at M.I.T., I have left to join Raytheon Co.'s Research Division in Lexington. I am working on the development of monolithic microwave circuits using galium arsenide and similar materials." . . . **David O. Overskei,** Ph.D.'76, writes, "I am now head of the Doublet III Physics Group at GA Technologies, Inc., San Diego, Calif. We are working on controlled thermonuclear fusion research on the Doublet III Tokamak."

The following deaths have been reported to the Alumni Association, with no further details available: **Carl M. Copenhaver,** S.M.'65, of Knoxville, Tenn., on March 7, 1983; **Myron L. Williams,** S.M.'32, of Tombstone, Ariz., on November 2, 1982; **Robert W. Roop,** '48, unit manager at Lincoln Laboratory, Lexington, Mass., on June 2, 1983; **James W. Fry,** '50; administrator at Imperial Industries, Los Angeles, Calif., on June 14, 1978; **Andrew M. Lockett III,** Ph.D.'55, of Los Alamos, N.M., on October 1, 1983.

# X

## Chemical Engineering

Professor **Norman Beecher,** '44, of Tufts University, is editor of *Hazardous Waste,* a new quarterly journal of Mary Ann Liebert, Inc., Publishers, New York. Its purpose: to "help establish industrial waste technology as a firm scientific and engineering discipline. . . . A central source for . . . advancing technology . . . for providing economical and ecological methods for regulating and managing hazardous waste." Among members of *Hazardous Waste*'s Editorial Board: **Stanley E. Charm,** '52, of Tufts; **Michael Manning,** Sc.D.'76, lecturer at M.I.T.; **Michael Modell,** '60, of Modar, Inc.; and **Adel F. Sarofim,** Sc.D.'62, professor of chemical engineering at M.I.T.

**Margaret Hutchinson Rousseau,** Sc.D.'37, a retired process engineer and consultant with Stone & Webster Engineering Corp., Boston, was recipient of the 1983 Founders Award of the American Institute of Chemical Engineers (AIChE), for her pioneering efforts on the behalf of women in chemical engineering. Rousseau became the first woman member of the AIChE in 1945, and now she is the first woman in the organization's 75-year history to receive this major award. **Howard G. Hipkin,** Sc.D.'51, a consultant to the Bechtel Group in California, has been named a fellow of the AIChE, "for his outstanding work in data measurement within the energy industries." . . . **Robert L. Huffman,** S.M.'42, has retired from the DuPont Co. . . . **Thomas M. McCarthy,** S.M.'52, writes that he is "currently director of external technical relations at Procter and Gamble—Europe, responsible for government relations for P & G operations in Europe. I am actively involved in EEC activities through the American Chamber in Brussels, and was recently chairman of the Commission on Environment, International Chamber of Commerce."

**Irwin J. Gruverman,** S.M.'55, reports that in 1982 he founded the Biotechnology Development Corp., which completed its initial public offering on December 6, 1983. . . . **Joseph Reitgels,** S.M.'57, writes, "As of November 1, 1983, I was made manager of employee relations of the Chevron Research Co., Richmond, Calif." . . . **John Forgrieve,** S.M.'50, has retired this year from Exxon Chemical Co. . . . **Lawrence B. Galpin,** S.M.'68, has been promoted to senior technical service and applications development representative with the Films Division of ICA Americas, Inc. . . . **Robert S. Smith,** S.M.'47, writes that he has retired this past December from the Exxon Corp., after 36 years of service. His work in recent years was with large-scale linear programming models. . . . **Douglas D. McConnell, Jr.,** S.M.'42, reports, "Still enjoying retirement—living in Aptos on Monterey Bay, Calif. Have become active in local political activities—on the board of several organizations trying to promote better local government. Recently conducted a forum favoring offshore exploration."

**Earp F. Jennings, Jr.,** S.M.'39, retired in 1977 as chief engineer at Hercules, Inc., and is currently vice-chairman of the Delaware Solid-Waste Authority. . . . **Miren C. Salsamendi,** Ph.D.'82, has just accepted a position as a research engineer with the Experiment Station, E.I. du Pont de Nemours and Co., Wilmington, Del. . . . **Marc Machblitz,** S.M.'78, has recently transferred to Southern California to work as a project engineer in Chevron's El Segundo Refinery. . . . **Carlos A. Ramirez,** Sc.D.'79, reports, "After spending three years as process engineer at the Upjohn Co., Kalamazoo, Mich., I joined the Department of Chemical Engineering at the University of Puerto Rico. I am presently involved in a mad hunt for external funds to support several projects in biomedical engineering."

**Thomas Goodgame,** Sc.D.'53, was honored by Arkansas Governor Bill Clinton at the 1983 annual meeting of the Arkansas Federation of Water and Air Users with the title of an Arkansas Traveler. The award—first given to Franklin Roosevelt in 1941—is authorized by the Arkansas Legislature for presentation to outstanding citizens of other states who have traveled in Arkansas and distinguished themselves by their accomplishments. Goodgame's citation is for service to the state and people of Arkansas. . . . **Charles P. Marion,** Sc.D.'52, has been appointed chief technologist at Texaco Development Corp., White Plains, N.Y., the patent and licensing subsidiary of Texaco, Inc. Prior to this appointment he had been a senior staff coordinator in the Strategic Planning Department at Texaco, Inc. Marion notes that his son, G. Toby (Practice School, Course X, '71), is now serving on the staff of Caltex Petroleum in its Tokyo headquarters.

# XIII

## Ocean Engineering

**Professor J. Daniel Nyhart,** has been invited to be a member of a standing panel on international ocean law and policy. The panel was established in April 1982 by Citizens for Ocean Law, of which Elliot L. Richardson is chairman of the board. This is an organization formed toward the close of Law of the Sea Treaty negotiations to facilitate a flow of information on Law of the Sea issues and policies. . . . **Peter N. Mikhalevsky,** Ph.D.'79, has joined the department at M.I.T. as associate professor. He resigned from the U.S. Navy to assume this post. Formerly, he was the program manager for research and development at the Naval Military Personnel Command, Washington, D.C. He will be working closely with the department's Arctic acoustics group.

**Professor T. Francis Oglivie,** department head at M.I.T., was elected a fellow of the Society of Naval Architects and Marine Engineers at the Society's annual meeting in November. He is also faculty adviser to a new student section of SNAME being formed by Course XIII students. The New England Section of SNAME has given the new section their blessing, and we have obtained approval by the National Executive Committee. . . . **Roderick M. White,** Sc.D.'56, has retired as academic dean of the U.S. Coast Guard Academy and is now the executive director of the Coast Guard Academy Foundation. We congratulate Dr. White on both counts.

The fourth annual Robert Bruce Wallace Lecture will he held on April 23, 1984, at M.I.T. The lecture series was established as a gift from Mr. and Mrs. A.H. Chatfield to bring advanced ideas in ocean engineering to the M.I.T. community and the public. Mrs. Chatfield is the daughter of **Robert Bruce Wallace,** '98, who made major contributions to the development of Great Lakes shipping. The lecturer this year will be Bertram Herzog of Herzog Associates, and the title of the lecture: "Computer-Aided Design in Engineering." Interested persons should contact Ms. Mary Kreuz at (617)253-4330.

**Barry C. Roberts,** '63, a retired captain of 31 years with the U.S. Coast Guard, has accepted a position with Daedalean, Inc., Woodbine, Md., a company specializing in design, engineering, and fabrication in the mechanical engineering field. Roberts will head the organization's Washington office located in Alexandria, Va. . . . **W. M. Nicholson,** S.M.'48, has been recently appointed as a member of the Marine Board of the Assembly of Engineering, National Research Council. . . . **Albert F. Suchy,** S.M.'80, is currently serving as engineer officer of the U.S. Coast Guard cutter *Bear*, whose home port is Portsmouth, Va. Suchy now holds a professional engineer's license from the state of Washington for naval architecture and marine engineering.

**John M. Chiffer,** S.M.'83, reports, "Since graduating I have joined the U.S. Navy on active duty, graduated from Officer Candidate School on October 1, 1983, and am now attending Navy Nuclear Power School, Orlando, Fla. After nuclear power training, I will join the Navy's submarine fleet aboard a nuclear fast-attack-class submarine as a nuclear power plant officer." . . . **Walter Lincoln,** '75, has recently accepted a position as chief of the Ocean Engineering Branch of the Coast Guard Research and Development Center, Groton, Conn. . . . **Lanny Benham,** S.M.'77, is presently residing in northern Virginia and was recently promoted to vice-president (mechanical engineering) of the Benham Group, Inc., a nationally recognized architectural and engineering design firm. . . . **Deborah R. Sides,** S.M.'82, reports, "Working for Science Applications, Inc., Monterey, Calif., doing environmental review of offshore oil and gas development plans in the Santa Barbara Channel. Also interested in satellite remote sensing for marine resource applications and computer-based, image-processing, geographic information systems for marine resource assessment."

**Barry S. Brissenden,** '54, a supervisor with the Marine and Ports Division of the Department of Development, Halifax, Canada, passed away on October 23, 1982. . . . **Alexander Sledge,** '33, a retired Navy captain, passed away in Highland Park, N.J., on August 3, 1983. . . . **Joseph E. Flynn,** S.M.'37, of Winter Park, Fla., passed away on September 24, 1983; no details are available.—Patricia A. LeBlanc-Gedney, Administrative Officer, M.I.T., Room 5-228A, Cambridge, MA 02139

# XIV

## Economics

Two volumes of *Essays in International Economic Theory* by **Jagdish Bhagwati,** Ph.D.'67, Lehman Professor of Economics and director of the International Economics Research Center at Columbia University, were published in January by the M.I.T. Press ($45 each). Both were edited for publication by **Robert C. Feenstra,** Ph.D.'81, who is assistant professor of economics at Columbia. Bhagwati is described as "a foremost theorist in the area of international

# Engineering vs. Management? No, They're Really a Partnership

## *But Engineering Takes Depth, says Kerrebrock*

**By Donald M. Davidoff, '86 A. & A.**

DONALD M. DAVIDOFF

**Too many students severely undervalue the M.I.T. faculty, says Professor Jack L. Kerrebrock. Professors are more than dispensers of fact, he insists.**

*Like most M.I.T. faculty members, Professor Jack L. Kerrebrock, head of the Department of Aeronautics and Astronautics, is no stranger to Washington. But when he took a two-year full-time NASA assignment as associate administrator for aeronautics and space technology (in charge of NASA's three research centers and its research in aeronautics and space technology) in 1980, Professor Kerrebrock found Washington full of surprises. Some of them, he told me, hold lessons for M.I.T. and its students. I found Professor Kerrebrock's comments on students and their problems of special interest, for few faculty in my experience seem to have a sense of what it's like to be a student here. Professor Kerrebrock does.*

*Here are some excerpts from my conversation with Professor Kerrebrock early this winter, just a few months after he had returned to Cambridge:*

**D.M.D.:** How did your experience at M.I.T. relate to your work in Washington?

**Kerrebrock:** I've been in the aerospace field for 25 years, 23 of them at M.I.T. So I've served on many advisory committees for NASA, and I've had a lot of professional interaction with NASA people. I thought I pretty well understood the organization. But when I got there, I found I really didn't.

**D.M.D.:** How so?

**Kerrebrock:** People's perceptions from the outside of how a government agency operates are always different from their perceptions from the inside. It's only by being on the inside that you understand where the sources of initiative are, who has control and who doesn't, and what can be done and what can't. In particular, the interactions of the budgetary system are complex. It's easy for us on the outside to be critical of the way the system wants to manage its research grants. But on the inside you discover that it's an extraordinarily complex problem with a lot of different people with different interests pushing and pulling in all directions. What comes out really depends on a very complicated system for dealing with this.

**D.M.D.** In light of all these non-technical influences on an engineer's decisions, do you feel that M.I.T. is adequately preparing its students for the challenges of tomorrow?

**Kerrebrock:** I think so.

The most important thing to learn in engineering school is that there is no fixed body of information on which you can base your career and do things constructively for the rest of your life. You have to continue to learn new things and essentially regroup what you already know.

Another one of the important things about engineering is that you have to work with people: it isn't strictly a technical activity. You have to understand people with different viewpoints and get them to cooperate, particularly as you get to more senior positions. At entry level, generally speaking, an engineer is likely to be given a technical job with a well-defined scope. But the first thing you have to do in order to advance is to understand how your work fits with others' and to work with others to make the job better. You soon find that there is no clear distinction between engineering and management.

**D.M.D.** Given this underlying idea that engineering and management are partners, how should M.I.T. be doing better?

**Kerrebrock:** I think there's a risk here—it's tempting to forget that management has to act on technical information. It's true that engineers have to deal with a very complex set of issues. But the basic point is that engineers have to deal in depth. I still believe that it is important for engineers to have technical depth in at least one area, so they can understand what is meant by a rational approach to a problem. In spite of the fact that there is a trend away from management knowing the technical aspects of engineering, I don't think that a broad overview of technology is adequate preparation for engineering management.

**D.M.D.:** Is this the way it works at M.I.T. now—in your department and the Institute in general?

**Kerrebrock:** Our objective in this department is to introduce the students to a philosophy of aerospace engineering as well as to the technical disciplines. We try to get the students to understand how aeronautics and astronautics is successfully done by the best practitioners. It is somewhat different than other departments. Aerospace engineers design, develop, and operate very, very complex and expensive systems. In a sense we kind of lead the engineering world in the management of complexity. That may seem like an audacious statement; a lot of people think of complexity in terms of communications technology and miniaturized mainframe computers. But I think aerospace engineers by and large have the most challenging problems.

**D.M.D.:** Do you think your department, and the Institute in general, have adequately addressed the issue of human relations in an engineering career?

**Kerrebrock:** We try to do that by example. I would say that the most important thing that a student can get from M.I.T.—better than from any other engineering school—is contact with the faculty—a large, well-qualified faculty. And I'm afraid too many students don't understand that. They think of the faculty mainly as dispensers of fact, which is severely undervaluing them. The factual information available at M.I.T. is not really very different from what's available at any other college, or even a library.

**D.M.D.:** How do you see the relationship of faculty and undergraduates at M.I.T.?

**Kerrebrock:** It's important for the faculty to spend enough time to do their formal teaching competently and effectively, of course. But the teaching of undergraduates shouldn't be just a matter of getting a certain set of facts onto a blackboard. I think it's even more important that faculty spend time talking to students about more general ideas. For example, why are they doing the kind of research that they are doing? I think that kind of information is at least as valuable to the undergraduate student as anything else.

**D.M.D.:** Speaking of a good rapport between faculty and students, what provisions does your department have for receiving input from students?

**Kerrebrock:** I think that the faculty of this department are very receptive to suggestions, though they may not seem to solicit them. That means, to a considerable extent, the feedback depends on student initiative; the individual student going in and talking to the faculty member. We have a student advisory committee which has been more or less active over the years, and I think it can serve a very important function. But there is no formal mechanism that forces students and faculty to come together.

**D.M.D.:** What happens when students don't succeed in those contacts?

**Kerrebrock:** You have to recognize that the educational system around M.I.T. is not something that has been created overnight. We've been doing this for a large number of years, and the faculty around here do rather have the impression that they know how to do it. They're not going to agree with students who think it is all wrong, and a revolution is in order. On the other hand, the system isn't perfect; it can be improved if it's approached from the viewpoint that there is a lot that is good in it but that refinement is still in order. Then I think everybody is pretty receptive to suggestions.

I think it depends on personal initiative. Unfortunately, only a small fraction of people exert leadership, and those who do can have a very large effect on others. I encourage students to get ahold of the faculty and make constructive suggestions. That's the best method, and in order for it to function effectively, a number of students are going to have to spend some time on it.

trade"; the first volume in the series is devoted to theory of commercial policy, the second primarily to international factor mobility—tax jurisdictions, foreign investment vs. labor imports, and international migration of skilled labor.

**Eric A. Hanushek,** Ph.D.'68, chairman of the University of Rochester's Department of Economics, was appointed February 1, 1984, deputy director of the Congressional Budget Office. . . . **Michael R. Dohan,** Ph.D.'69, writes, "I founded a new company called Family Financial Consultants, Inc., to provide lectures and fee-only consulting to middle-income, single women and the elderly. I continue to teach economics and do research at Queens College, Flushing, N.Y." . . . **Alice Kidder,** Ph.D.'67, former associate professor of transportation at Syracuse University, has been appointed associate professor of management at Babson College, Wellesley, Mass., and also director of the College's Office of Sponsored Research.

**David S. McClain,** Ph.D.'74, has been promoted to associate professor of finance and economics in the School of Management at Boston University on September 1, 1983. . . . **Frank C. Colcord,** Ph.D.'64, is currently the dean of the faculty of arts and sciences at Tufts University, Medford, Mass. . . . **J. Philip Cooper,** Ph.D.'72, formerly vice-president and general manager of the Securities Products Division of Interactive Data Corp., Waltham, Mass., has been promoted to senior vice-president of the division.

Three notices of death have been received by the Alumni Association, with no further information available: **Warner G. Baird, Jr.,** '42, of Chicago, Ill., on August 9, 1981; **David M. Bridgham,** '44, of Boston, on November 20, 1983; and **Robert B. Perry,** '42, of Oxnard, Calif., on December 1, 1983.

# XV

## Management

Associate Professor **Richard Goodman,** S.M.'62, of the Graduate School of Business at the University of California, Los Angeles, is co-author of *Modern Management Techniques in Engineering and R & D* (New York: Van Nostrand Reinhold, 1983, $38.50). The book is described as a reference manual on "the roles of administration in an industrial environment," with advice on staffing, recruiting, and promoting technical personnel as well as tips on personnel selection and staffing.

**John F. Lubin,** S.M.'49, management professor at the University of Pennsylvania's Wharton School, has been named a director of Data General Corp., Westboro, Mass. . . . **Leon Liebman,** '67, writes, "I am living over half my time in England—and welcome vistors. We started new Interactive Market Systems efforts in Asia, Australia, and Belgium. Late in 1983 we acquired Leading National Advertisers (LNA), following our earlier acquisition of Rome Reports." . . . **Eric Herzog,** Ph.D.'73, writes that he is president of his own management consulting firm in Pacific Palisades, Calif., with clients in aerospace, banking, manufacturing, oil, utilities, and cities. Jane, his wife, is a silkscreen artist and his daugther Kim will enter kindergarden in the fall.

**Randel B. Fischer,** S.M.'68, is currently vice-president of finance and administration at Amoco Canada Petroleum Co., Ltd., Calgary, Alberta, a wholly-owned subsidiary of Standard Oil Co. (Indiana). . . . **J.S. Andrasick,** S.M.'71, has been promoted to executive vice-president of C. Brewer & Co., Ltd., an international agribusiness conglomerate. . . . **Richard N. Pigossi,** S.M.'65, is serving as regional vice-president (Indonesia and Philippines) for Private Investment Company for Asia, S.A., an investment bank based in Singapore. It is owned by 250 international banks and corporations supporting development projects in Asia. . . . **Giyora Doeh,** S.M.'58, writes, "Am enjoying involvement in coordinating a Sloan School alumni group in the Los Angeles area. Upcoming dinner meeeting with Dean Siegel, then another with former classmate Ed Roberts in the spring should be memorable events." . . . **Fred Shinagel,** S.M.'55, has been ap-

pointed managing director of mergers and acquisitions at Dean Witter Financial Services, Inc., New York City, in the firm's Capital Market Division. . . . **Gregory F. Zaic,** S.M.'72, former development manager for the American Can Co., Greenwich, Conn., has joined the Cambridge Research and Development Group of Westport (Conn.) as director of new products and ventures.

### Management of Technology Program

**Geoffrey N. Andrews,** S.M.'82, is staying very busy at Pilkington P.E. in North Wales. He writes he had a paper published in the November/December 1983 issue of *Research Management* and over the last year has delivered electro-optics technical presentations in London, Stockholm, and Boston. . . . **Charles A. Berry,** S.M.'83, is in the United States as of this writing and is expected to come to M.I.T. on January 26 for a visit with Ed Roberts and the current program students. He has been in California this trip and stopped off to visit with **Julian Nikolchev,** S.M.'83, at SRI International, where the two of them made a phone call to Jane Morse. . . . **Richard H. Bullen,** S.M.'82, wrote Jane Morse a note in November. He and Chris "discovered sailing in Long Island Sound" last summer. He reports that Chris is pregnant with their second child. Rick is staying very busy at Bullen Management Co., managing the automation of his business. He says he has a great new concept for a technology investment strategy.



**Carol M. Lemlein,** S.M.'83, will be at the Sloan School placement office recruiting for Teradyne in February. She is looking forward to having lunch with all the current program students while she's here. . . . **James C. Tagliaferro,** S.M.'83, is manager of Advance Manufacturing Systems at Centronics, Hudson, N.H. He writes that the past year has not been easy, as his father passed away in October. He and Joyce sent Jane Morse a Christmas card and reported that they and the children were all doing very well, however.—Jane Morse, Program Manager, M.I.T., Room E52-125, Cambridge, MA 02139

# XVI
## Aeronautics and Astronautics

Inertial navigation devised by **Charles S. Draper,** '26, and his associates in the late 1940s is among the top ten engineering achievements of the past half-century, according to the National Society of Professional Engineers. NSPE compiled the list as part of its 50th anniversary; other notable achievements include nylon, nuclear power, the ENIAC computer, transistors, the Boeing 707, pacemakers, lasers, Telstar, and Project Apollo.

The need of the department at M.I.T. for computer-aided design and manufacturing facilities has been met by gifts of Perkin-Elmer Corp. and CADAM, Inc., a subsidiary of Lockheed. Hardware from the former and software from the latter each valued at about $250,000—together with a $50,000 operating fund from Lockheed—"will greatly enhance" our ability to teach current techniques in aerospace design, says Professor Jack L. Kerrebrock, head of the department, and will also be significant in many research activities. The gifts are in honor of **Hall Hibbard,** '28, who rose through the ranks after he joined Lockheed in 1932 to become a top executive before retiring in 1972.

**Philip D. Shulter,** S.M.'64, a retired Marine Corps lieutenant general, has taken on the post of director of Syscon Corp., Washington, D.C. . . . **Kenton J. Ide,** S.M.'59, is senior vice-president of the Boston Safe Deposit and Trust Co., a subsidiary of the Boston Co., Inc. . . . **Daniel M. Spadone,** S.M.'76, writes, "At present I am the deputy project manager for battleships and cruisers in the Naval Sea Systems Command, Department of the Navy, Washington, D.C." . . . **Mel L. Suarez,** S.M.'77, has left the Draper Laboratory, Cambridge, to open an office for Agora Systems, Inc., in the Boston area. Suarez will be consulting in inertial navigation problems. . . . **John H. Sweeney III,** S.M.'60, writes, "I am now in my third year as engineering manager of the Hinckley Yacht Co. in Southwest Harbor, Maine (on Mount Desert Island). Hinckley produces 10 to 15 auxiliary sailing boats each year."

**Courtland Perkins,** S.M.'41, formerly president of the National Academy of Engineering, has retired as a member of the board at the Draper Laboratory. . . . **Richard A. Scheuing,** S.M.'48, has been elected a vice-president of Grumman Aerospace Corp., Bethpage, N.Y.; he is in charge of the Grumman Research and Development Center. . . . **Robert L. Townsend,** S.M.'43, has retired from the navy and Grumman International to consult in the Washington area. . . . **Michael Dyment,** S.M.'79, is president of Dyonix, Inc., Ottawa, Canada, which provides management and venture capital assistance to start-ups in high-technology product development.

# XVIII
## Mathematics

**Ronald Pannotoni,** Ph.D.'79, writes from Franklin, N.C., that he is working on a contract research project in acoustics sponsored by the Office of Naval Research. . . . **Jan Boal,** Ph.D.'59, reports her two recent publications: "Permutable Primes," *Mathematics Magazine,* January 1982 (with Jean Bevis); and "Continued Fractions and Interactive Processes," *Two-Year College Mathematics Journal* March 1982 (with Jean Bevis). She also reports that her son Robert married Laura Jones on June 11, 1983, her daughter Virgina married Douglas Jamieson on March 19, 1983, and her daughter Emily Ann Wert had a son, James William III, on May 24, 1983. An eventful year! . . . **Peggy T. Strait,** S.M.'57, is author of *A First Course in Probability and Statistics With Applications,* published by Harcourt Brace Jovanovich, Inc., in 1983.

# XIX
## Meteorology

**John R. Seesholtz,** Ph.D.'68, Capt., U.S.N., was assigned as oceanographer of the Navy on October 14, 1983. . . . **Stephen Whitaker,** S.M.'77, writes, "I have taken a position as staff scientist with Atmospheric Instrumentation Research, Inc., Boulder, Colo., and am working in microprocessor controlled instrumentation research and development." . . . **Robert M. White,** president of the National Academy of Engineering, Washington, D.C., has been elected a director of the Charles Stark Draper Laboratory, Inc., Cambridge. . . . **Peter R. Tatro,** Ph.D.'66, is corporate vice-president and manager of technology and ocean sciences at Science Applications, Inc., McLean, Va.

**James E. Jiusto,** '53, research professor in the department of atmospheric sciences at the State University of New York, Albany, passed away on October 5, 1983. He was a recognized national and international expert on fog and weather modification; adviser to the Federal Aviation Administration; assisted in the World Meteorological Organization in designing an international weather modification experiment; and was a consultant to the National Science Foundation in atmospheric science modification.

# XXI
## Humanities

Hungarian folk music has been a major passion of **Stephen Erdely,** professor of music, and now his long-term studies of this field are to be aided by a substantial grant from the National Endowment for the Humanities. With collaboration from other American and Hungarian scholars, Erdely will contrast the folk music of Hungarian migrants to the U.S. with that of those who stayed in the Hungarian countryside. The goal: "some broad philosophical principles" about how an alien culture affects the folk traditions of migrants. In studies last summer of urban and rural groups in Hungary, Erdely concluded that there is substantial resistance to change: ". . . a strong music tradition existing for 1000 years will not change in 40 to 50 years," he reported.

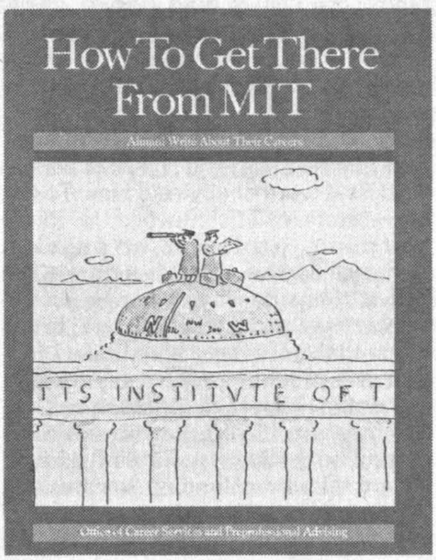
### Technology and Policy Program

As of this writing, **Steve Izatt,** S.M.'84, will be joining a research group looking into new policies and technologies for the steel industry at Bethlehem Steel Corp. in February 1984. . . . **Warren Schenler,** S.M.'83, has accepted a position with Energy and Resource Consultants, Boulder, Colo. . . . **Paul Hauge,** S.M.'83, is working for Jason M. Cortell and Associates, Inc., Waltham, Mass., an environmental consulting and planning firm. . . . **Bobby Gillenwater,** S.M.'80, has become an attorney with the law firm of Barnes and Thornburg, Washington, D.C. He is working primarily with intellectual property law (patents, trademarks, copyrights, etc.), but is also doing regulatory-related work.

**Leslie Klein,** S.M.'83, has accepted a position with the Transportation Systems Center, Washington, D.C. . . . **Lissa Martinez,** S.M.'80, has been named the first awardee of the National Academy of Engineering Fellowship and will be organizing symposia as part of the NAE's Third Decade Focus on Technology and Policy.—Richard de Neufville, Chairman, Technology and Policy Program, M.I.T., Room 1-138, Cambridge, MA 01239

# Many Roads to Many Careers

## *Choose the Byways, Not the Highways, says Weatherall*




**In "How to Get There From M.I.T.," Robert K. Weatherall, director of career services, writes that roads to careers are less superhighways than byways that cross and recross. And Jeannette Gerzon, associate director of career services, urges the importance of dreaming a bit. "It's our dreams that hold the clues to our careers as well as to our happiness," she tells students.**

Students tend to think of M.I.T. departments and courses as highways—the straight, fast routes to careers, each leading in a different direction never to meet any of the others again.

Not so, says Robert K. Weatherall, director of career services and preprofessional advising. The roads have lots of intersections—not straight and narrow at all.

As Weatherall surveys the traffic into his office—heavy at this time of the year—he's acutely aware of the dilemmas, even trauma, of students as they try to plot out their future careers. They think too simplistically, he believes, too easily assuming that their goal is a superhighway to the "in" field of the moment.

Three false assumptions here, says Weatherall:

□ It's not a question of a single superhighway. Career paths cross and recross. Mathematicians find themselves working on computers, computer experts on buildings and bridges, materials specialists in economics and even venture capital. Wherever you think the excitement is, he tells students, you can get there from almost anywhere.

□ There is no such thing as the single "in" field. Action in one field of engineering—computers and electronics, for example—stimulates action in others—for example, materials, manufacturing, even chemistry. ("After all," says Weatherall, "it was not only the miners who made money in the Gold Rush. The makers of shovels also did very well, and the wagon-builders, and the bankers.")

□ The "in" field may not be the right one for everybody. Better to follow your dream, leaving what seems to be the superhighway for what many think is a byway if your dream seems to be down that road. Hence the advice of Jeannette Gerzon, associate director of career services: People who are most successful in their careers make play into work and work into play. "Finding fulfillment has a domino effect: we work better, share

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more easily, contribute more, and create more happiness around us," she says.

**Electrical Engineer Turned Publisher**

After trying to convey these messages to the countless students and alumni who nervously scan the bulletin boards and sign up for interviews in their office, Weatherall and Gerzon decided on a new strategy: ask alumni to write for students about how *their* careers unfolded, what was important and what not so important, why they made the choices they did and what happened.

The result is the first issue of what Weatherall plans will be an annual "magazine," a 72-page book in which 29 alumni let down their hair.

**Shirley Jackson,** Ph.D.'73 Phys., turns out to be the exception to Weatherall's rule—no byways here at all: she's been in physics ever since her first year at M.I.T. as an undergraduate. No regrets: "There's always something new and something intriguing." But Jackson joins the chorus of laid-back advice: "You cannot make absolute predictions about how your life will go. . . . If I had tried to sit back and plan exactly what my life would be like, I would never have learned what I have."

Government service? No course of study is available, says Congressman **Les Aspin,** Ph.D.'65 Econ. "The career paths you can choose are as varied as the types of government careers available." And because Washington offers an "exciting and demanding atmosphere," Aspin says, the chances to move from job to job—and field to field—are very good. The key to success in all of them: ability to deal with large volumes of information and "to understand the processes by which decisions are made. . . ."

**O. Reid Ashe,** '70 E.E.C.S., traces his "love affair with newspapers" to *The Tech*, but he has no regrets over four years of electrical engineering at M.I.T. When he finally broke down the doors of a small daily, being able to change fuses was handy—but writing was what really made the difference. Now, as publisher of the *Jackson Sun*, Ashe finds electrical engineering occasionally useful for management decisions on videotext, teletext, and databases. But his enthusiasm for journalism—far off the curve as far as engineering is concerned—is contagious.

When **Andre R. Jaglom,** '74 Phys./Mgmt., signed on at M.I.T., he expected to study physics—no plans at all to become a lawyer. But after two years he was restless with physics laboratories, wanting something more "people-oriented," so he turned to Course XV—and finally to law. Now an attorney in New York, Jaglom says "almost any M.I.T. program will give you a jump on law school. . . . The precise and rigorous analytical thinking that one learns in four years at M.I.T. is remarkably similar to the kind of analysis required of a good lawyer."

Two reasons why **Kate H. Hadley,** Ph.D.'75, chose to study earth and planetary sciences: she liked dealing with "concrete problems," and she wanted work that took her outdoors. So now she sits "in an office in downtown Houston and facilitates the preparation of exploration, production, and crude oil transporation costs for potential discoveries in arctic and deep-water locations." It's a job that requires only a small fraction of what Hadley learned at M.I.T., she writes, but that doesn't matter. "What you study . . . is not important. The habits you teach yourself and the attitudes you form are what counts. Beyond the basics, study things you want to learn, and learn from that how to teach yourself."

Ask **Terry M. Copeland,** Ph.D.'78 Chem.Eng., what he expected after he finished Graduate School at M.I.T., and the answer is a research job in polymers. And that's what he had for three years. Then came two years of marketing—something entirely different, except that Copeland was selling what he had been making. Now he's in production—superintendent of a manufacturing facility, a third big change. Clearly, Copeland says, the idea that an engineer with a Ph.D. is locked into research is simply wrong.

**Plenty of Freedom: No Vested Interest**

For a final word of advice, "How To Get There from M.I.T." turned to Philip Morrison, professor of physics: "Change is the chief certainty," he writes. "A path where change is foreseeable may make a better route to the future than one whose breadth and convenience of footing are visibly inviting at the start." But then Morrison has second thoughts: "No generalities can approach the usefulness of an early growth toward self-understanding, one nutured in a complex soil of chance, impulse, and circumstance, and by the sun and shade of deliberate reflection."

To this task today's students bring great power, says Weatherall. They are often faster to recognize new opportunities than their teachers, who have vested interests in the old ones. The difficulty is that this speed of recognition can be misleading, pointing students toward transient targets of opportunity, down highways instead of byways.

## Obituaries

B. A. Thresher

### B. Alden Thresher, 1897-1984
### Leader in College Admissions

B. Alden Thresher, '20, who managed the process by which more than 20,000 students were admitted to M.I.T. between 1936 and 1961, died at his retirement home in Winter Park, Fla., of heart failure on January 23. He was 87.

During his 25 years as M.I.T.'s director of admissions, Professor Thresher became recognized as a "dean" among U.S. admissions officers. For much of that period he was associated with the College Entrance Examination Board, of which he served as chairman in 1958-60, and he was later on the board of the Educational Testing Service.

President Emeritus Julius A. Stratton, '23, who headed M.I.T. at the time of Thresher's retirement in 1961, paid tribute to his "outstanding contributions to the theory and practice of his profession. He led the way in developing a quantitative system of analysis in admissions," Dr. Stratton said, "and in achieving more effective communication between secondary schools and colleges and universities.

"His analytical approach, his willingness to experiment, his integrity and humanity, and his deep concern for the welfare of the students justifiably brought him wide recognition."

Thresher joined M.I.T. in 1929 to teach economics, a field he had studied at Harvard following his undergraduate work in management at M.I.T. He rose to become full professor in the department before being asked to take charge of the Institute's admissions—an assignment which he later described as "congenial"; clearly, it was a good deal more than that.

### Robert S. Harris, 1904-1983
### Pioneer in Nutrition Research

Robert S. Harris, '28, professor of nutritional biochemistry, emeritus, in the Department of Nutrition and Food Science, died of Alzheimer's disease in Newton, Mass., on December 24; he was 79.

Dr. Harris was widely known for research on the roles of vitamins, minerals, fats, and proteins in the metabolic process. He had also made important studies of the relation of diet to dental caries, and he was an outspoken proponent of fluoridation of water supplies as a strategy for improving dental health.

Dr. Harris joined the M.I.T. teaching staff immediately upon receiving his Ph.D. in chemical biology in 1932, and he served continuously from then until his retirement in 1969. During this period he developed new courses in nutrition and biochemistry for M.I.T. students and also participated in efforts to improve nutrition education in developing countries; he was for many years a member of the Expert Committee on Nutrition of the World Health Organization.

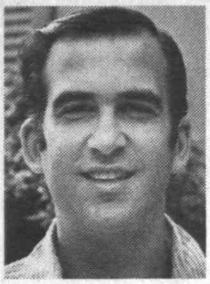
### Deceased

**George M. Roads, Jr.,** '10; January 6, 1984; 1395 Simpson Ferry Rd., New Cumberland, Penn.
**Max C. Sherman,** '10; July 1982; Eastern Shore Estates, Centerville, Md.
**Seth H. Seelye,** '12; September 1978; 210 Springwood Dr., Spartanburg, S.C.
**Raymond J. Cunningham,** '14; June 15, 1983; 474 E 14th St., Brooklyn, N.Y.
**James S. Stewart,** '15; 1981; 619 Hayes Ave., Fremont, Ohio.
**Victor Y. Dunbar,** '16; July 6, 1983; RR1, Bras D'Or, N.S., Canada.
**Elmer B. Haines,** '16; August 25, 1982; 325 Church St., Hartford, Conn.
**Edgar F. Hanford,** '16; November 5, 1983; 15 Roselawn, Hammond, Ind.
**Frederick Leslie Ford,** '17; January 6, 1984; 12 North Dr., Marion, Mass.
**Edward B. Payne,** '17; September 4, 1983; 10 Emerson Pl. Apt. 4D, Boston, Mass.
**Adolph H. Wenzell,** '17; December 11, 1980; Onteora Club, Tannersville, N.Y.
**Stanton L. Burgess,** '18; December 15, 1983; 801 Chestnut St. No. 908, Clearwater, Fla.
**Wilfred R. Holt,** '18; December 13, 1983; 1256 Cheyenne Blvd., Madison, Tenn.
**Amos N. Prescott,** '19; December 1, 1983; 347 Hamlet Hills No. 113, Chagrin Falls, Ohio.
**Roger B. Colton,** '20; January 1978, 624 Hunting Towers E, Alexandria, Va.
**Harry J. Kahn,** '20; December 3, 1983; Providence House, Providence St., Worcester, Mass.
**Jacob Novack,** '20; July 28, 1983; 100 Centre St. Apt. 1202, Brookline, Mass.
**Solomon M. Passell,** '20; August 1982; 16180 Oxley Rd., Southfield, Mich.
**B. Alden Thresher,** '20; January 23, 1984; 1111 S Lakemont Ave., Winter Park, Fla.
**Gunnar Ring Amundsen,** '21; December 12, 1972; Ingar Nilsensvei 3, Oslo, Norway.
**Ethan A. Beer,** '21; January 26, 1978; 4134 Holman Ln., St. Louis, Mo.
**Gustav C.W. Carlsson,** '21; October 23, 1983; Idalavagen 2, 18274 Stocksund, Sweden.
**Julius Gordon,** '21; October 26, 1983; 106 Dakota Ave., Wilmington, Del.
**Edwin C. Brown,** '22; November 5, 1981; 1169 Hillsboro Mile Apt. 703, Hillsboro Beach, Fla.
**John G. Campbell,** '22; November 9, 1982; 3117 Carol Woods, Chapel Hill, N.C.
**Walter L. Hunt,** '22; September 6, 1983; 6 Church, Unadilla, N.Y.

**William R. Nichols,** '22; October 10, 1982; 611 Alameda Blvd., Coronado, Calif.
**Everet Allan Reinhardt,** '22; 1983; c/o Country Manor, 180 Low St., Newburyport, Mass.
**Thomas H. West,** '22; January 3, 1984; Box P183, South Dartmouth, Mass.
**Joseph T. Martin,** '23; March 29, 1981; Westminster Health Care Center, Bethel Park, Muncie, Ind.
**William H. Couch,** '24; December 30, 1983; 82 Dimmock St., Quincy, Mass.
**William Earl Messer,** '24; December 21, 1980; c/o Casassa, 459 Lafayette Rd., Hampton, N.H.
**Joseph E. Smith,** '24; 1982; 6 Mill St., Dorchester, Mass.
**Harold Bishko,** '25; November 21, 1983; 6184 Agee St. No. 189, San Diego, Calif.
**Merle E. Hutchins,** '26; May 7, 1981; 2214 Lakeside Blvd., Manitowoc, Wisc.
**Robert R. Brown,** '27; September 7, 1983; c/o R. Roderick Brown '59, 79 Hemenway Rd., Framingham, Mass.
**Raymond F. Hibbert,** '27; November 30, 1983; 32 Wilshire Rd., Madison, Conn.
**Erik Hofman,** '27; November 26, 1983; Reservoir Nursing Home, 1841 Trapello Rd., Waltham, Mass.
**George E. Calef,** '28; August 31, 1983; 269 Locust St., Danvers, Mass.
**Robert S. Harris,** '28; December 24, 1983; 32 Dwhinda Rd., Waban, Mass.
**Holbrook E. Metcalf,** '28; November 20, 1983; 420 Bay Ave No. 613, Clearwater, Fla.
**Stewart H. Newland,** '28; November 16, 1982; 1200 Johnston Rd., Lot 12-18, Dade City, Fla.
**Kommenus M. Soukaras,** '28; June 26, 1983; 2310 NW 15th St., Miami, Fla.
**Fred P. Walden,** '28; August 3, 1983; Manor House Rm. 134, 1001 Middleford Rd., Seaford, Del.
**Walter A. Key,** '29; April 9, 1983; Carrollton Manor Apt. A4, 5324 Carrollton Ave., Indianapolis, Ind.
**Arnold S. Ackiss,** '30; March 2, 1979; 4972 Loehne 3, Koblenzer Str 31, Wolfenduttel, West Germany.
**James S. Carey,** '30; November 1, 1983; 1537 E Hillsboro Blvd. No. 641D, Deerfield Beach, Fla.
**Guido H. Hunziker,** '30; June 19, 1980; Muhlebergweg Baden, Switzerland.
**Charles W. Lyle,** '30; December 13, 1982; 445 Quaker Bottom Rd., Havre De Grace, Md.
**Smedley D. Butler, Jr.,** '31; May 25, 1983; Box 252-B, Kitty Hawk, N.C.
**John A. Norton,** '31; 1983; 143 Merrick Rd., Lynbrook, N.Y.
**Frederick A. Ritchie,** '31; January 3, 1984; 35 Hundreds Rd., Wellesley, Mass.
**Alexander C. Burr,** '32; August 30, 1977; c/o Mrs. Hugh McCreery, 232 Ave. C West, Bismarck, N.D.
**Charles L. Davis, Jr.,** '32; May 4, 1979; PO Box 173, Flagler Beach, Fla.
**Myron L. Williams,** '32; November 2, 1982; PO Box 486, Tombstone, Ariz.
**Arnold M. Fedde,** '33; March 22, 1983; 3512 SE Cora Apt. 4, Portland, Ore.
**Paul J. Johnson,** '33; July 14, 1983; 2415 Avenel Ave. SW, Roanoke, Va.
**Oliver J. Moreland,** '33; March 1982; 3701 SW Condor Apt. 3K, Portland, Ore.
**William L. Sheppard,** '33; July 5, 1983; 4240 Riverview Blvd., Bradenton, Fla.
**Richard A. Tutein,** '33; July 8, 1982; PO Box 128, Quincy United Methodist Home, Quincy, Penn.
**Ricardo C. De La Torre,** '34; 1979; 650 Calle Estado, Miramar, P.R.
**John C. Lewis, Jr.,** '35; November 23, 1983; 2918 N 20th St., Tacoma, Wash.
**Arthur M. Linn,** '35; May 2, 1983; 3834 Farmbrook, Sylvania, Ohio.
**Francis B. Sellew,** '35; November 23, 1983; 28 Wellesley Ave., Wellesley, Mass.
**Karekin G. Arabian,** '37; November 24, 1982; 376 Dover Dr., Walnut Creek, Calif.
**Arnett E. Benton,** '37; May 1982; 1372 San Pablo Dr., San Marcos, Calif.
**Frank R. Leonard,** '39; June 16, 1982; PO Box 147, Cannon Beach, Ore.
**Charles N. Levy,** '39; May 28, 1983; 13535 Ronnie Way, Saratoga, Calif.
**Kenneth E. Madsen,** '39; October 19, 1983; 258 Miraflores Dr., Palm Beach, Fla.
**Russell A. Schiffmann,** '39; September 15, 1983; 106 St. Andrews Dr., Vienna, Va.
**John S. Breitenstein,** '40; April 14, 1983; 2323 N Main, Bethlehem, Penn.
**Paul S. Neblett,** '40; August 11, 1983; 7521 Benedict Dr., Dallas, Tex.
**Warner G. Baird, Jr.,** '42; August 9, 1981; 103 East Bellevue Pl., Chicago, Ill.
**Robert B. Perry,** '42; December 1, 1983; 4825 Corbina Way, Oxnard, Calif.
**J. Douglas Brawner,** '43; September 18, 1982; 3412 Sentinel, Midland, Tex.
**Frances L. Kraft Golden,** '43; December 7, 1983; 585 B Avenida Majorca, Laguna Hills, Calif.
**John Goldsmith,** '43; August 19, 1983; 1828 Via Visalia, Palos Verdes Pen, Calif.
**Walter H.F. Stenken,** '43; 1979; 15 Beechwood Rd., So. Fort Mitchell, Ky.
**David M. Bridgman,** '44; November 20, 1983; 1 Emerson Pl. No. 14D, Boston, Mass.
**Harold W. Rambusch, Jr.,** '44; 1980; One 5th Ave., New York, N.Y.
**Robert L. Jacks,** '46; December 31, 1983; PO Box 358, Goss Dr., Middlebury, Conn.
**Leon J. Weymouth, Jr.,** '46; December 17, 1983; 19 Holly Ln., Mattapoisett, Mass.
**Emmett T. Craig,** '47; January 7, 1984; 1374 Knollwood Dr., Baton Rouge, La.
**Emil De Agazio,** '47; June 12, 1983; 82 Oak St., Stoneham, Mass.
**Theodore Hechler, Jr.,** '47; August 14, 1983; 228 Lookout Ln., Annapolis, Md.
**William C. Krutzsch,** '48; November 15, 1983; 3 Yorke Rd., Convent Station, N.J.
**Arthur F. Muldoon,** '48; January 19, 1984; 52 Woodland Rd., Andover, Mass.
**Albert V. Tashjian,** '48; October 16, 1983; 2416 Spruce St., Philadelphia, Penn.
**Orville Frank Tuttle,** '48; December 13, 1983; Handmaker Geriatric Center, Golding Pavilion, 2221 N. Rosemont Blvd. No. 2, Tucson, Ariz.
**John L. Wilson, Jr.,** '48; June 30, 1983; 6514 13th Ave. Dr. W, Bradenton, Fla.
**Francis L. Marran,** '49; March 16, 1981; 220 Bay Ave., Patchogue, N.Y.
**Raymond C. Gardner,** '50; May 4, 1981; 118 Beech St., Henderson, Nev.
**Aldro I. Lingard,** '50; January 2, 1984; 1277 Bay Shore Dr., Valparaiso, Fla.
**John J. McHugh,** '50; November 7, 1983; 5636 Olde Post Rd., Sylvania, Ohio.
**Edith A. Roberts,** '51; March 8, 1977; 180 Derby St., Salem, Mass.
**Alfred Sudhalter,** '51; December 20, 1980; 64 Metropolitan Ave., Roslindale, Mass.
**Kaspar Habosian,** '52; January 16, 1984; 35 Arden Rd., Watertown, Mass.
**Gustave A. Nylander,** '52; September 2, 1981; 470 High St., Mount Holly, N.J.
**James E. Jiusto,** '53; October 5, 1983; 28 Pinewood Rd., Guilderland, N.Y.
**Kyuichiro Washizu,** '54; November 25, 1981; 2-32-12 Wada, Suginami, Tokyo, Japan.
**Andrew M. Lockett III,** '55; October 1, 1983; 101 Cascabel, Los Alamos, N.M.
**Joseph T. O'Connor,** '55; December 27, 1983; 41 Washington St., Newton, Mass.
**Kwan D. Park,** '55; October 31, 1983; 1507 South King St., Honolulu, Hawaii.
**Robert R. Dingle Kemp,** '56; January 11, 1984; 16 Copperfield Dr., Kingston, Ont., Canada.
**Frank A. Russo,** '58; April 8, 1981; 312 Jodyway, Lutherville, Md.
**Theodore W. Leet,** '60; 1983; c/o John Hancock Mutual Life Insurance Co., PO Box 930A, Detroit, Mich.
**Joseph S. Goldberg,** '63; January 25, 1984.
**Victor C. Blanco,** '68; October 16, 1983; c/o Observatrio Interamericano, De Cerro Tololo, Casilla 63-D, La Serena, Chile.
**Marvin J. Essrig,** '74; 1981; 1013 Frankland Rd., Tampa, Fla.
**Martha F. Nelson,** '80; January 5, 1984; 915 Sherman St., Schenectady, N.Y.
**Guice B. Vander Linder III,** '81; February 23, 1983; c/o Mrs. and Mrs. G.B. Vander Linden, 1427 Olino St., Honolulu, Hawaii.

# No Way of Knowing the Time of Day?

## Puzzle Corner/Allan J. Gottlieb



Allan J. Gottlieb, '67, is associate research professor at the Courant Institute of Mathematical Sciences of New York University; he studied mathematics at M.I.T. and Brandeis. Send problems, solutions, and comments to him at the Courant Institute, New York University, 251 Mercer St., New York, N.Y. 10012.

Let me begin with thanks to everyone who sent us best wishes for the holidays. David especially asked me to thank Phelps Meaker for the lovely card.

It has been two years since I reviewed the criteria used to select solutions for publication. Let me do so now.

As responses arrive during the month, they are simply put together in neat piles, with no regard to their date of arrival or postmark. When it is time for me to write the column, I first weed out erroneous and illegible solutions. For difficult problems, this may be enough; the most publishable solution becomes obvious. Usually, however, many responses still remain. I next try to select a solution that supplies an appropriate amount of detail and that includes a minimal number of characters that are hard to set in type. A particularly elegant solution is, of course, preferred. I favor contributions from correspondents whose solutions have not previously appeared, as well as solutions that are neatly written or typed, since the latter produce fewer typesetting errors.

### Problems

**APR1** We begin this month with a bridge problem from Doug Van Patter:

North:
♠ Q 10 3
♥ Q 7
♦ A Q J 8 6 4
♣ J 9

West:
♠ 9 8 7
♥ 8 3
♦ 10 9 7 5 2
♣ A 10 6

East:
♠ J 6 5 2
♥ J 10 7 2
♦ –
♣ Q 8 5 4 2

South:
♠ A K 4
♥ A K 9 5 4
♦ K 3
♣ K 7 3

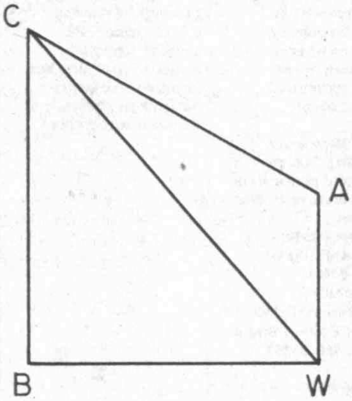
You are West, defending against a six no-trump contract. Suspecting that you may have a diamond stopper, you lead the ♣ A. Do you still expect to set this contract? If so, how.

**APR 2** Nob Yoshigahara has sent us an unusual cryptarithmetic puzzle, a multiplication problem involving time:

```
    x  xx
       xx
 ----------
 x  xx  xx
```

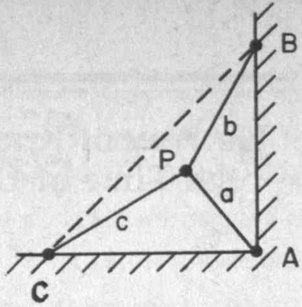
Each of the 10 digits is to be used once. The first number represents minutes and seconds; the third, hours, minutes, and seconds; and the leftmost digit of each number is nonzero.

**APR 3** A. Singer wants to know how fast you can commute:




A commuter lives at C and works at W. He normally drives to work via road CW. Occasionally, to break the monotony of the daily commute, he drives to Town A and from there to W. On still other occasions he drives to Town B and from there to W. Towns A and B are each exactly 10 miles from W and roads BW and AW are at right angles. Our commuter always travels at the same speed, regardless of route. His normal trip takes exactly 30 minutes, his trip through Town A takes him 35 minutes, and his trip through Town B takes him 40 minutes. At what rate of speed does he travel?

**APR 4** Harry Zaremba's rods are loose; how large a triangle can they determine? In the figure (*next page*), rigid rods of lengths a, b, and c are hinged at point P, and rod a is hinged to the intersection of the vertical and horizontal surfaces. If the free ends of the rods b and c are




always maintained in contact at B and C and permitted to slide along the surfaces, what is the maximum area of the right triangle CAB that can be formed by the rod extremities? (For uniformity and simplicity, let the constant $K^2 = b^2 + c^2 - a^2$.)

**APR 5** The M.I.T. undergraduate math club plays with an infinite chessboard but no chess pieces. The squares of an infinite chessboard are numbered by putting zero in the corner and in each other square putting the smallest nonnegative integer that does not appear to its left in the same row or below it in the same column. Find a nonrecursive formula for the number placed in row i column j.

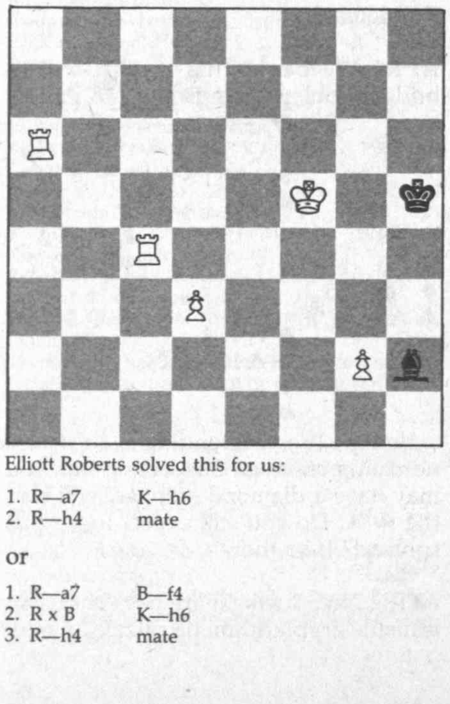
### Speed Department

**SD1** Phelps Meaker wants to know a simpler way to write the sequence 1, 8.825, 31.544, 77.88, 156.99, 278.38, . . . As a hint he reminds you that the sixth term is greater than 216.

**SD2** Joan Baum found the following query in the *New York Times*: If it is 10 a.m. in New York and 5 p.m. in Moscow, what time is it at the South Pole? At the North Pole?

### Solutions

N/D1 White is to play and mate in three:



Elliott Roberts solved this for us:

| | |
|---|---|
| 1. R—a7 | K—h6 |
| 2. R—h4 | mate |

or

| | |
|---|---|
| 1. R—a7 | B—f4 |
| 2. R x B | K—h6 |
| 3. R—h4 | mate |

or

| | |
|---|---|
| 1. R—a7 | B—c7 |
| 2. R(a7) x B | K—h6 |
| 3. R—h4 | mate |

Also solved by Kenneth Bernstein, Avi Ornstein, Robert Bart, Walter Nissen, Matthew Fountain, Winslow Hartford, David Krohn, Norman Wickstrand, Miguel Colina, Ronald Raines, and the proposer, George Farnell.

**N/D2** Cancelling d's to give
dy/dx = y/x
is known as "freshman's folly." But similar jokes occasionally work for arithmetic:
64/16 = 4/1
326/163 = 2/1
Can anyone find a four-digit counterpart?

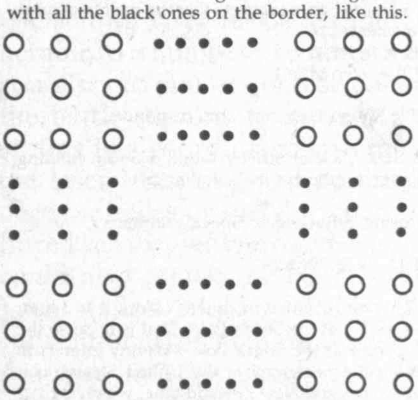
Philip Klenn did so, with acknowledged assistance from Radio Shack:

I was challenged by your "freshman's folly" problem and programmed my Radio Shack home computer to solve it by trial and error. I was surprised to see the large number of possible solutions to the problem, 60 by my count. Naturally, I ignored any four-digit numbers containing a zero, since even a freshman knows that cancelling zeroes is indeterminate. Incidentally, my computer was particularly slow—it took a run of 14 hours to check all possibilities.

| | | |
|---|---|---|
| 3926/1963 = 2/1 | 9891/2198 = 9/2 | 8324/6243 = 8/6 |
| 6392/3196 = 2/1 | 2164/1623 = 4/3 | 8432/6324 = 8/6 |
| 6938/3469 = 8/4 | 2168/1626 = 8/6 | 8464/6348 = 4/3 |
| 9386/4693 = 8/4 | 3244/2433 = 4/3 | 8644/6483 = 4/3 |
| 9998/4999 = 8/4 | 3248/2436 = 8/6 | 8648/6486 = 8/6 |
| 8565/2855 = 6/2 | 3284/2463 = 8/6 | 8756/6567 = 8/6 |
| 6664/1666 = 4/1 | 4216/3162 = 4/3 | 8864/6648 = 8/6 |
| 6748/1687 = 4/1 | 4324/3243 = 4/3 | 9188/6891 = 8/6 |
| 7348/1837 = 4/1 | 4328/3246 = 8/6 | 3157/1353 = 7/3 |
| 7468/1867 = 4/1 | 4432/3324 = 4/3 | 9584/3594 = 8/3 |
| 7948/1987 = 4/1 | 4648/3486 = 4/3 | 2317/1324 = 7/4 |
| 9995/1999 = 5/1 | 4756/3567 = 4/3 | 4627/2644 = 7/4 |
| 9564/1594 = 6/1 | 4832/3624 = 8/6 | 6937/3964 = 7/4 |
| 8176/1168 = 7/1 | 4864/3648 = 4/3 | 7231/4132 = 7/4 |
| 9373/1339 = 7/1 | 6448/4836 = 4/3 | 7462/4264 = 7/4 |
| 9793/1399 = 7/1 | 6484/4863 = 4/3 | 7693/4396 = 7/4 |
| 1761/1174 = 6/4 | 6488/4866 = 8/6 | 5946/4955 = 6/5 |
| 6665/2666 = 5/2 | 7564/5673 = 4/3 | 6824/4265 = 8/5 |
| 9772/2792 = 7/2 | 7568/5676 = 8/6 | 2925/2275 = 9/7 |
| 8919/1982 = 9/2 | 8216/6162 = 8/6 | 9162/7126 = 9/7 |

Also solved by Dennis Sandow, Harry Zaremba, Winslow Hartford, Matthew Fountain, Walter Nissen, Jr., Robert Bart, and Kenneth Bernstein.

**N/D 3** When the conversation grew dull at a party, I discovered that equal numbers of red and black checkers could be arranged in a rectangular tray, with all the black ones on the border, like this.



But when my back was turned, one of the guests ate a few of each color, thinking my checkers to be cookies. I found that I still had an equal number of black and red checkers, and that I could still arrange them in an array with the reds inside and the blacks on the border. How many checkers did I start with, and how many were eaten?

Unfortunately, the diagram printed (unlike the proposer's original) inadvertently suggested that the black border was three checkers wide. Under this interpretation Miguel Colina writes:
The rectangular array that contains the red checkers is of size M × N, and the number of black checkers that surround the red ones is 36 + 6M = 6N. Since there is an equal number of red and black checkers, we have that M × N = 36 + 6M + 6N. Solving for M, we obtain M = (36 + 6N)/(N − 6). The constraints are that both M and N must be integers, and that N must be greater than 6.

To solve this problem, I used my personal computer. A simple program that had a looping variable N was used to find integer values for M. The following data was found:

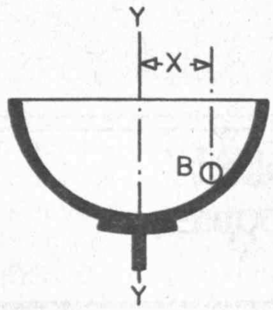
| *N* | *M* | *M x N* |
|---|---|---|
| 7 | 78 | 546 |
| 8 | 42 | 336 |
| 9 | 30 | 270 |
| 10 | 24 | 240 |
| 12 | 18 | 216 |
| 14 | 15 | 210 |

Of the 15 possible combinations of starting and ending numbers of checkers, I chose the one with the smallest difference (starting with 216 and ending with 210 of each color) because of the hint that only a few were eaten. Therefore, we must have started with a total of 432 checkers, and 12 checkers were eaten.

Walter Nissen, Jr. was able to deduce that the indented border is just one checker wide. His solution is 60 at the outset, 12 eaten:
Assuming that the border is only 1 checker wide (I had a hard time deducing this from the diagram which is square and does not distinguish red and black), there was a 5 × 12 array with a 3 × 10 center, and after 12 checkers were eaten there was a 6 × 8 array with a 4 × 6 center. If the border is two or more checkers wide, various gluttonous and even more indigestible solutions emerge. Where the width of the border is x and the dimensions of the red rectangle are h and w, the number of reds must equal the number of blacks in the border, hw = 2wx + 2hx + 4xx. (If Euler could use this notation so can I, especially as superscripts are a pain.) Solving for w, w = (2 hx + 4xx)/(h − 2x). For positive, integral h, find positive, integral w. If x = 1, the only solutions are h = 3,4.

Also solved by Kenneth Bernstein, Avi Ornstein, Matthew Fountain, Winslow Hartford, Harry Zaremba, Norman Wickstrand, Mary Lindenburg, and Gene Henschel.

**N/D 4**




A hemispherical bowl with a radius of 1 foot 1 inch is mounted on a central vertical shaft YY. A one-pound ball B with a radius of 1 inch is free to roll inside the bowl. On what part of the bowl's surface will the ball tend to ride (i.e., what will be the value of x) if the bowl is spun at 50 R.P.M. about the YY axis? How do you explain this peculiar result? Show that x will increase to about 7 inches at a speed of 60 R.P.M.

Kenneth Bernstein found the ball by looking at the bottom of the bowl!
In the frame of the spinning bowl, the ball experiences a force of 32 lb. vertically downwards and ($w^2 \sin\theta$) horizontally away from the central shaft YY ($\theta$ is the angle between YY and the radius of the bowl drawn to the center of the ball). The resultant force must be directed away from the center of the bowl to ensure that, at equilibrium, there is no net force acting to change x. Thus:
$\tan\theta = (w^2 \sin\theta)/32$

One solution is always $\theta = 0$. The other solution, when possible, is
$\cos\theta = 32/w^2$
If $w < \sqrt{32}$, then the second solution is extraneous. In the first part of this problem
$w = 2\pi\ 50/60 \text{ rad/sec} < \sqrt{32}$.
In this case only the solution $\theta = 0$ obtains. The ball remains at the bottom of the bowl and either spins, if there is friction, or remains motionless in the absence of friction. In the second part, $w = 2\pi > \sqrt{32}$ so that the second solution leads to x = 7.028 inches. In both parts there is an equilibrium at x = 0; however, for the second part this equilibrium is unstable while for the first part it is stable.

Daniel Whitney noted a similar problem that caused great consternation in 8.01 (M.I.T. freshman physics). In this example we spin a cylinder containing water.

Also solved by Thomas Harriman, Bruce Calder, John Prussing, Harry Zaremba, Winslow Hartford, Matthew Fountain, Walter Nissen, Jr., Robert Bart, Norman Wickstrand, and Kenneth Bernstein.

**N/D 5** Find two five-digit perfect squares that together contain all ten digits. How many solutions exist?

Sidney Shapiro found eight solutions:

| | *N(1)* | *N(2)* | $N(1)^2$ | $N(2)^2$ |
|---|---|---|---|---|
| (1) | 126 | 153 | 15876 | 23409 |
| (2) | 126 | 198 | 15876 | 39204 |
| (3) | 144 | 228 | 20736 | 51984 |
| (4) | 144 | 309 | 20736 | 96481 |
| (5) | 174 | 228 | 30276 | 51384 |
| (6) | 174 | 309 | 30276 | 95481 |
| (7) | 195 | 219 | 38025 | 47961 |
| (8) | 252 | 267 | 63504 | 71289 |

All the Ns are divisible by 3.

Also solved by David Krohn, Avi Ornstein, Robert Bart, Walter Nissen, Jr., Matthew Fountain, Winslow Hartford, Harry Zaremba, Thomas Harriman, Frank Carbin, Phelps Meaker, and the proposer, John Rule.

**Better Late Than Never**

**1983 M/J 4** Frank Rubin points out that the twin prime conjecture is now a theorem and the argument given for **M/J 4** must be augmented to give special treatment to low values.

**M/J 5** Frank Rubin has a simpler solution.

**JUL 1** Sidney Williams has offered a simpler solution.

**JUL 4** Mark Nagurka and Anthony Standen have responded.

**JUL 5** Laurie Fabens reports that the next two number elements are
$3114^2 = 9696996$
$81619^2 = 6661661161$

**OCT 2** Naomi Lieberman has responded.

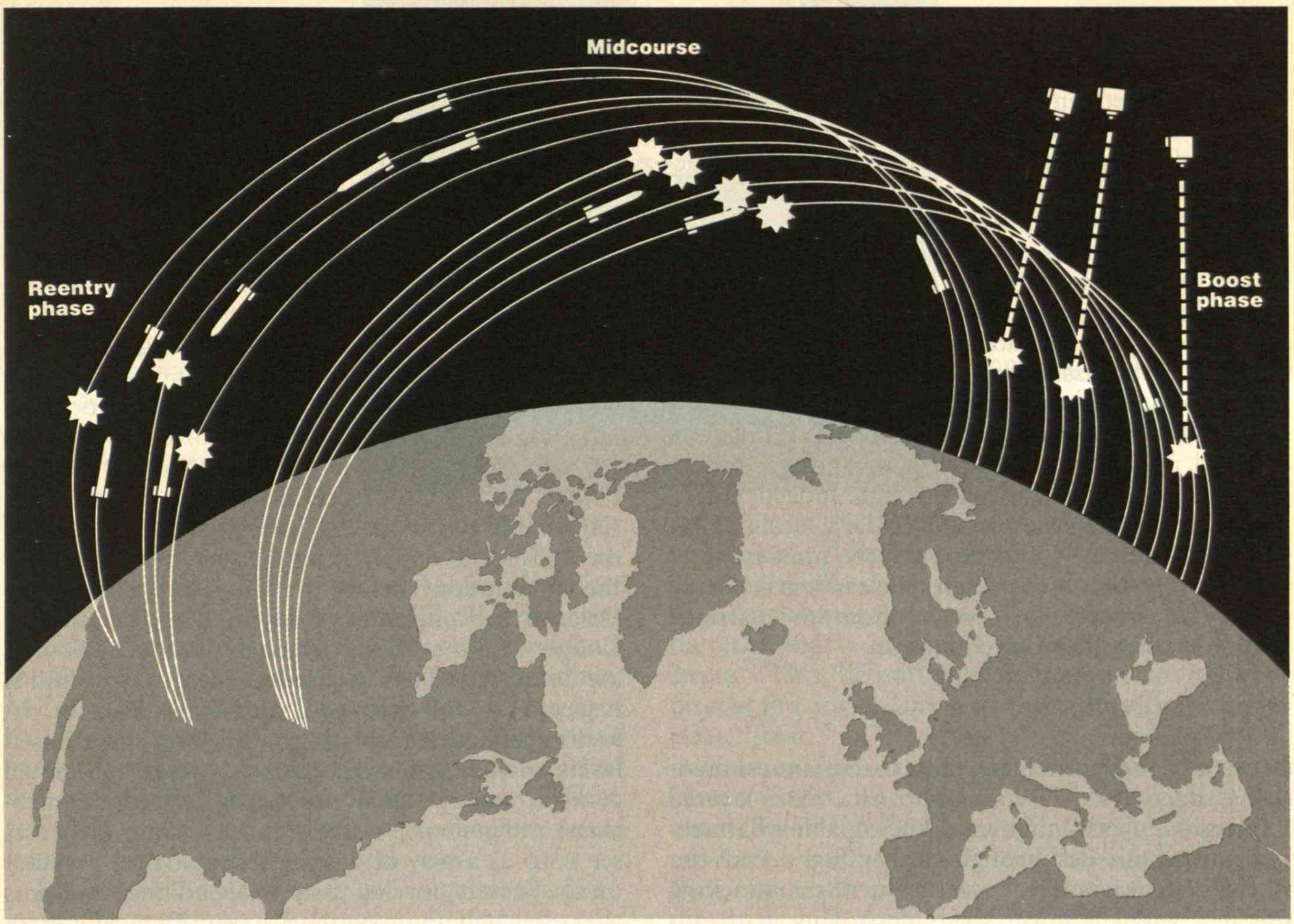
**N/D SD1** Michael Strieby found a South holding that contra-indicates the solution given

**Proposers' Solutions to Speed Problems**

**SD1** 1X,2X,3X,5X,6X.

**SD 2** When it is 10 a.m. in New York it is 3 a.m. the next day at the South Pole. That is because the only people at the South Pole with any interest in time are the personnel at the United States polar station. They use New Zealand time, which is Eastern standard time plus 17 hours, because the polar station is supported from the American base at McMurdo Sound, which in turn is supported from Christchurch, New Zealand, and it is convenient for the time to be the same at all three. The North Pole is uninhabited, so there is no one to care what time it is; of course, strictly speaking, where all the meridians that govern local time converge, as they do at the poles, there is no way of defining the time of day.

**The basic trajectory of ballistic missiles provides defensive systems with three separate but unequal opportunities to shoot them down. The boost phase lofts missiles above the atmosphere. During the midcourse section, individual reentry vehicles are released to coast along free-fall trajectories. On reentry, the missiles explode above their targets. Although missiles can be attacked anywhere, they are most vulnerable late in the boost phase.**




enormous cost.

Orbiting laser battle stations might also be vulnerable to a number of countermeasures. The Soviets could try to jam or confuse communications among the battle stations to prevent the system from operating in a coordinated fashion. They could deceive the lasers' tracking and pointing mechanisms with decoy missiles or metallic chaff, or "blind" their infrared sensors with ground-based lasers. The Soviets could also attack the laser battle stations directly. Each station could probably defend itself against conventional interceptor missiles and space mines by shooting indiscriminately at anything that entered a large "keep-out zone." But as Gerald Ouellette points out, there is no way to defend satellites against nearby nuclear explosions in space. Thus, the most effective method would be to attack the system with nuclear warheads encased in laser-resistant armor, timed to explode at the appropriate altitude.

An even more intractable problem concerns command and control of a laser BMD system in space. For lasers to be effective against Soviet missiles in the last two to three minutes of boost-phase flight, they would have to be fired on extremely short warning. This means that either the laser battle stations would have to make the decision to shoot automatically, without human intervention, or a high military officer with access to real-time surveillance information (such as the chief of the North American Aerospace Defense Command or the commander of an orbiting military command post) would be able to activate the system within two minutes of a Soviet missile launch. In both cases, obtaining authorization from the president or other top officials would be impossible.

Since firing a laser BMD system would not involve using nuclear weapons offensively, the decision to do so could theoretically be made without presidential control. Nevertheless, such a move would constitute an act of war (albeit in response to a perceived

DRAWING: OMNIGRAPHICS

act of war on the part of the Soviets), and the potential for further escalation would clearly be present. No American president would be likely to delegate authority over decisions of war and peace to such an extent. Moreover, any accidental destruction of a Soviet civilian spacecraft by the laser BMD system would be a serious provocation.

Finally, even advocates admit that no laser BMD system would be perfect. Since the battle stations would have to engage hundreds of targets in rapid succession, there would be no time to determine whether each missile had been "killed" by waiting for it to diverge significantly from its trajectory. Thus, a statistical averaging method would have to be used, which would allow a certain fraction of undamaged missiles to leak through. Indeed, even a 95 percent effectiveness against a large-scale ballistic-missile attack would probably be impossible to achieve. Yet because a single nuclear warhead can destroy an entire city, 5 percent of the Soviet arsenal could devastate the United States.

**Defense in Depth**

Because of these problems, most BMD planners favor using space-based lasers as part of a three-layered "defense in depth" that would be capable of attacking ballistic missiles throughout their flight. Each tier of the system would take out some of the attacking missiles, with the lower layers destroying warheads that managed to slip through the upper ones.

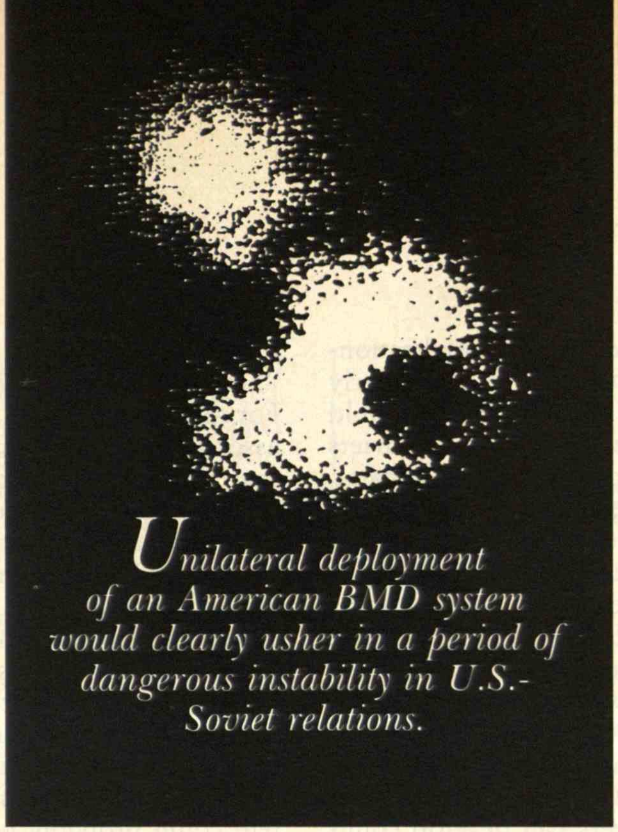
A constellation of space-based laser platforms would serve as the first tier of the system. These platforms would be capable of destroying about 50 percent of the missiles in a large-scale attack. The MIRVs that penetrated this layer would be attacked outside the atmosphere by long-range homing missiles, which would destroy the reentry vehicles by dispensing a hail of pellets or shrapnel. The remaining MIRVs would theoretically be eliminated by a tier of interceptor missiles operating within the atmosphere, such as the army's Low Altitude Defense System (LOADS).

In its report to the president, the Fletcher study team concluded that an effective layered defense would require, at a minimum, a permanent manned presence in space, construction of an enormous new rocket capable of lifting heavy objects into orbit, deployment of over 100 "complex and expensive" satellites, and thousands of ground-based interceptor missiles. Not surprisingly, cost estimates for a layered defense range from $200 billion to more than $500 billion (one-sixth of the U.S. gross national product). Says Lee Bradley, a physicist at M.I.T.'s Lincoln Laboratory, "The potential payoff is so high that it's hard to imagine a cost that wouldn't be worth it." Nevertheless, such huge expenditures would probably be politically unacceptable, particularly as no one could guarantee that the system would be leakproof.

Although the Soviets are heavily engaged in research on high-energy lasers, the extent to which this work is militarily directed, and its sophistication relative to U.S. efforts, are matters of debate. In the March 1983 edition of its publication *Soviet Military Power*, the Defense Department stated that the Russians could test a space-based laser BMD system in the 1990s and deploy it by the turn of the century. But in testimony before the House Appropriations Defense Subcommittee, DARPA Director Richard Cooper said that in his personal view, "The Soviets are not ahead of us" in directed-energy research. He neglected to add that the United States leads in virtually every other technology needed for space-based lasers, including microelectronics, optics, automated control, radar, signal processing, telecommunications, and guidance systems. Indeed, some advocates see BMD as a way of putting technological pressure on the Soviets, forcing them to spend huge amounts to try to catch up. According to Gen. Daniel Graham (ret.) of the Heritage Foundation, a space-based BMD system would be a "technological end-run on the Soviets."

**Strategic Implications**

Assuming that a laser BMD system could be built at a reasonable cost, would it enhance the national security of the United States in the long run? Advocates contend that, should nuclear deterrence ever fail, a strategic defense would ensure that the United States would not be completely destroyed: recovery would still be possible. In this view, BMD is needed as insurance against an irrational Soviet decision to attack—or to block an attack from another nuclear power against either the United States or a third country. Analysts who believe that the U.S. land-based missile force is vulnerable to a Soviet first strike (a conclusion that many dispute) also see BMD as a means of shifting the strategic balance back in




favor of the United States.

But BMD advocates go one step further. They contend that the movement of both adversaries toward defensive strategies would ultimately improve stability. In his March 23 speech, President Reagan implied that if both the United States and the Soviet Union built effective BMD systems, then offensive nuclear weapons would become obsolete. The current condition of "mutual assured destruction" would be replaced by "mutual assured survival."

Reagan failed to point out that BMD would ensure stability only if both sides deployed their defensive systems at the same rate and had equal confidence in their effectiveness. To move to a stable condition of "defense dominance," an agreement would have to be negotiated specifying that both sides would gradually reduce their levels of offensive nuclear weapons as they introduced defensive systems. Thus, the ratio of defensive to offensive weapons would increase over a period of several years.

Because of the U.S. lead in BMD technology, however, the transition to defense dominance would probably be stable only if the United States agreed to share its technology with the Soviet Union, on the principle that "good fences make good neighbors." But such a high degree of military cooperation between the superpowers seems unlikely in the foreseeable future. As a result, one side (probably the United States) would deploy its BMD system first, thereby gaining a distinct strategic advantage.

Although a first-generation BMD system probably could not prevent a massive Soviet attack from devastating the United States, it could be quite effective in blunting a limited attack. The system would therefore be most advantageous in an offensive role—blocking any retaliation to a U.S. first strike against Soviet strategic forces. No preemptive attack could possibly wipe out the adversary's entire nuclear arsenal. But a limited BMD system could shoot down the small fraction of Soviet missiles that were not destroyed on the ground, keeping the attacker's losses to "acceptable" levels.

Even if the United States had no intention of striking first, its capability to do so would appear very threatening to the Soviet Union. After all, adversaries always interpret each other's capabilities in the worst possible light. Indeed, in an interview in *Pravda* on March 26, 1983, then-Soviet General Secretary Andropov responded to President Reagan's speech with just such a worst-case analysis. By developing a BMD system, he said, the United States would be seeking to secure "the possibility of destroying, with the help of ABM defenses, the corresponding strategic systems of the other side; that is, of rendering it incapable of dealing a retaliatory strike." This, he said, was tantamount to "a bid to disarm the Soviet Union in the face of the U.S. nuclear threat."

Thus, unilateral deployment of an American BMD system would clearly usher in a period of dangerous instability in U.S.-Soviet relations. If the Soviets did not have a comparable system, they might fear that their national survival was at stake and try to shoot down the U.S. defense. Even if the Soviets did not take this drastic action, their fears of a preemptive strike would make escalation of any severe crisis to general nuclear war much more likely.

What if both sides deployed defensive systems? For defense dominance to be stable, both superpowers would have to have enough faith in their defensive shields to abandon the threat of massive retaliation as the ultimate guarantor of deterrence. But since a BMD system could never be tested under realistic conditions, neither country would likely be so confident that it would stop relying on offensive weapons. Thus, each side would seek to maintain the credibility of its retaliatory force by developing ways to penetrate the other's defense.

An American strategic defense would therefore force the Soviets to build many more nuclear weapons so that they would still be capable of devastating the United States. Because nuclear warheads are relatively cheap (about $1 million apiece), they can be produced in quantities large enough to saturate any

ballistic-missile defense. (Indeed, the orginal rationale for American deployment of MIRVs in the early 1970s was to ensure that U.S. nuclear weapons could penetrate a planned Soviet ABM system.) The Soviets would probably also start producing cruise missiles, which fly at very low altitudes, beyond the range of space lasers. The United States is already deploying these "winged bombs" on submarines.

Moreover, despite the Reagan administration's rhetoric about making nuclear weapons obsolete through defense, the Pentagon is already studying how to penetrate a future Soviet BMD system. Under a program operated by the Defense Nuclear Agency at a yearly cost of $3.5 million, pieces of U.S. ICBMs have been exposed to lasers modeled after those used in Soviet research, so engineers can develop countermeasures. DARPA is also working on laser-resistant materials. And according to R. Jeffrey Smith, writing in *Science* magazine, a little-known U.S. effort called the Advanced Strategic Missile System program is engaged in designing, constructing, and testing "advanced penetration aids" such as chaff, decoys, and maneuverable MIRVs. All these programs are designed to overcome any possible Soviet BMD.

In sum, as military analyst Thomas Karas has written, "As long as both sides are determined to maintain it, assured destruction is bound to be mutual." In other words, ballistic-missile defense cannot remove the nuclear Sword of Damocles hanging over our heads. Instead of neutralizing the balance of terror, it would only increase the risk of nuclear war.

### The Impact on International Politics

Laser BMD would also have important ramifications in international politics. Although a strategic defense might shield the U.S. mainland from the brunt of a ballistic-missile attack, it could not destroy Soviet intermediate-range missiles such as the SS-20s targeted on Western Europe and East Asia, or battlefield nuclear weapons such as short-range missiles and artillery shells. A defensive shield over the United States would therefore "decouple" the fate of this country from that of its overseas allies, undermining the credibility of the American "nuclear umbrella" and forcing the United States to rely on conventional forces in Europe as a deterrent to Soviet attack. Moreover, if both the United States and the Soviet Union deployed defensive systems, the assurance that their respective homelands would be sheltered might encourage them to initiate more "limited" conflict, including nuclear war in Europe. For these reasons, the North Atlantic Assembly (the association of NATO parliamentarians) has warned that a U.S. strategic defense would give rise to "a dangerous and divisive current within the alliance."

The impact of laser BMD on arms control is also troubling. The ABM Treaty of 1972 (as amended by the Protocol of 1974) limits each party to one ABM system composed of no more than 100 fixed, land-based interceptor missiles. The treaty also prohibits the "development, testing, or deployment" of mobile land-based ABMs or novel systems based in the air, at sea, or in space. Since antisatellite weapons are not restricted by the treaty, a limited laser BMD system could probably be deployed in the guise of an antisatellite system. But since a comprehensive BMD system would require many more battle stations than any conceivable antisatellite system, it would clearly conflict with the terms of the ABM Treaty. Indeed, according to the president's fiscal-1984 Arms Control Impact Statement, which was submitted to Congress in April 1983 under the terms of the Arms Control and Disarmament Act, the ABM Treaty's prohibition against space-based BMD systems "applies to directed-energy technology . . . used for this purpose. Thus, when such directed-energy programs enter the field-testing phase, they become constrained by these Treaty obligations."

X-ray lasers would violate two other major treaties as well. Because these lasers are powered by nuclear explosives, they are constrained by the Outer Space Treaty of 1967, which forbids placing "any objects carrying nuclear weapons" into orbit around the Earth. Testing of an x-ray laser in space would also violate the Limited Test Ban Treaty of 1963, which forbids testing nuclear weapons in the atmosphere, under water, or in space.

By breaking, or seeking to renegotiate, these major Soviet-American treaties, the United States would gain only a temporary strategic advantage while dealing a grave and perhaps fatal setback to the arms-control process. In his interview with *Pravda*, Andropov warned that if the United States developed a BMD system, "This would actually open the floodgates of a runaway race of all types of strategic weapons, both offensive and defensive." Would it be in our interest to replace the modest but valuable agreements of the past two decades with unrestrained military competition on Earth and in space?

The implications of turning space into another potential battleground should also be considered. Many experts feel that the "weaponization" of space is inevitable because the United States and the Soviet Union are increasingly dependent on military satellite systems for communications, intelligence, navigation, and command and control of far-flung nuclear forces. Because these satellite systems act as "force multipliers," amplifying the power of weapons, they would be priority targets in any nuclear war. Nevertheless, introducing destructive weapons into space would add a new and dangerous dimension to the arms race. For example, the sudden malfunction of a crucial military satellite (such as an early-warning system) might be misinterpreted as a Soviet attack and trigger nuclear war.

Placing weapons in space would also have a chilling effect on peaceful exploration and development of the "next frontier." Space offers extraordinary commercial opportunities in areas such as novel manufacturing processes, pollution-free industries, expanded civil communications, solar-power generation, and even tourism. But a menacing array of armed satellites, laser battle stations, and space mines would inhibit such peaceful uses by turning near-Earth space into a no-man's land. Finally, in diverting major resources to space weaponry, the United States would risk falling behind Japan and Western Europe in the race to develop space for peaceful purposes. Indeed, the fiscal-1983 budget for military activities in space exceeded the civilian NASA budget by $1.5 billion.

The search for strategic stability is as much a political problem as a technical one. Thus, political solutions must be attempted—in particular, the long, difficult, but essential process of negotiating an agreement to reduce the number of threatening, first-strike weapons on both sides. (The Soviet Union recently offered to negotiate a ban on all weapons in space—a proposal summarily rejected by the Reagan administration.) For all its frustrations, arms control is a much safer road to stability than a technological "solution" as costly, flawed, and provocative as laser BMD.

*JONATHAN B. TUCKER is an associate editor of* High Technology. *He has an M.A. in international relations from the University of Pennsylvania and was a fellow in the Military Studies Program at the Foreign Policy Research Institute in Philadelphia.*

# The BMD Debate: Déjà Vu

By Herbert Lin

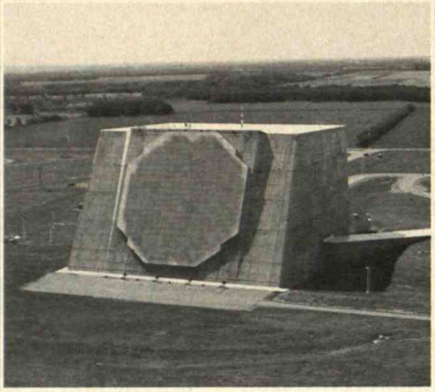
The more things change, the more they stay the same. During the sixties, defense experts debated whether protecting the United States from a nuclear-missile attack was feasible. That debate appeared to be settled in 1972 when the Anti-Ballistic-Missile (ABM) Treaty sharply limited both U.S. and Soviet defenses against missiles. The devastation that nuclear war would wreak on both countries was seen as a sufficient deterrent. However, President Reagan's "Star Wars" speech calling for a comprehensive research program on ballistic-missile defense (BMD) has rekindled the debate. Despite a decade of change, the arguments over BMD have a familiar ring.

### Some Things Change . . .

The technology has changed. The ABM systems developed in the sixties relied on nuclear-tipped missiles to intercept hostile warheads. Current BMD schemes call for lasers to destroy the hostile missiles shortly after launch. The revolution in electronics has dramatically improved the radar, computers, and other devices needed to detect a missile attack and direct a defense against it.

We also have another decade of experience using advanced technology in weapons systems. One such system, the Phoenix air-to-air missile, is designed to enable the F-14 fighter to shoot down six enemy airplanes simultaneously from more than 50 miles away. But, like the Phoenix, many high-technology weapons systems have never been fully tested, and informed people debate whether they have improved our military capabilities.

Nuclear doctrine has changed as well.



**This radar installation in North Dakota was the eye for the Safeguard missile defense system, dismantled in 1976.**

In the sixties, under Secretary of Defense Robert McNamara, it was mutual assured destruction—the deterrence of war by threat of retaliation. Since then, official U.S. doctrine has evolved toward planning to use strategic nuclear weapons against military targets. The Nixon and Ford administrations spoke of "flexible nuclear options," the Carter administration of "the countervailing strategy," and the Reagan administration of "prevailing in a protracted nuclear war." Recent Defense Department testimony before the Senate Armed Services Committee indicates that U.S. strategic nuclear weapons are aimed at Soviet nuclear forces, conventional forces, command posts, communications facilities, and war-supporting industries.

Finally, the international climate has changed. The ABM Treaty was signed at a time of reduced tensions, but the current diplomatic environment is chilly.

### . . . Others Never Change

Despite these changes, arguments about defense have remained remarkably similar. Consider points made on both sides of the ABM debate during the sixties. A profound dissatisfaction with mutual vulnerability as the basis for deterring war led some to support ABM systems. In 1969 Donald Brennan, regarded by many as the intellectual father of the pro-BMD position, wrote, "We should prefer live Americans to dead Russians." He argued that the Department of Defense should protect Americans and that ABM systems would do so.

In the sixties, supporters of ABM argued that the Soviets were hard at work on such a system, so we needed our own to maintain the strategic balance. As the Joint Chiefs of Staff argued, an ABM system would deny the Soviets an "exploitable capability" against the United States.

The vulnerability of the United States was thought to inhibit our government's ability to act. In particular, U.S. willingness to use nuclear weapons to defend Europe came into question as soon as the Soviet Union could launch nuclear attacks on our country. In 1969 Brennan suggested that an American ABM system would help reassure Western Europe that we would indeed be willing to protect it under our nuclear "umbrella."

Finally, technology has always offered the promise of a more secure future. In 1967 Secretary of the Army Stanley Resor stated, "The technical feasibility of the NIKE-X [ABM system is] generally accepted. All major engineer-


dom. We can choose to focus our nation's effort on systems that can defend us without harming people. We may follow some blind alleys, but if we make a broad effort to explore our options, while turning our backs on the technologies of mass destruction, we just may succeed.

Perhaps the most significant result of the president's speech has been a shift in the priorities of the defense establishment—from offensive technologies to those that could truly provide a defense. Years ago the Princeton physicist Freeman Dyson com-



PHOTO: U.S. ARMY

ing problems have been solved, and only minor design fixes are foreseen."

The arguments from the sixties can be compared to more recent comments. In 1983 President Reagan asked, "Would it not be better to save lives than to avenge them?" Advocates of BMD charge that the Soviets are ahead in the laser technologies that would be employed, and that we should therefore press ahead with research to preserve the strategic balance. The Fletcher panel, convened in 1983 to examine defensive weapons, argued that demonstrating an effective system would strengthen the U.S. military and diplomatic position. In 1980 Brennan wrote, "If we begin to make serious efforts to protect . . . our society, it would be likely to contribute postively to our credibility as the main guarantor of the [NATO] Alliance." Secretary of Defense Caspar Weinberger told the press in 1983 that he had no doubts that American ingenuity could create a total defense against all strategic weapons.

The arguments of BMD opponents have also changed little. They have maintained all along that the high speed and destructive power of nuclear missiles make defending against them extremely difficult. Any system that genuinely renders nuclear missiles impotent against cities would have to be essentially perfect, and technical perfection is nearly impossible.

One technical argument against BMD asserts that such a system would be vulnerable to enemy countermeasures. In 1968 Hans Bethe and Richard Garwin, well-known physicists with extensive experience in weapons technology, suggested inexpensive countermeasures to an ABM system. These included attacking or jamming the sensors for detecting incoming warheads, saturating the defense by sharply increasing the number of attacking missiles, and maneuvering the missiles or warheads to evade the defense. Bethe, Garwin, and others still point to these same methods as countermeasures to BMD systems.

A second technical argument asserts that even without countermeasures, BMD systems are unlikely to work. Any BMD system will be large and complex, opponents argue, and all large, complex systems are difficult to debug as well as hard to change in response to new threats. For example, if the enemy should change tactics in some unanticipated way, how long would it take to modify the huge computer program coordinating the defense? Changes in large computer programs sometimes take years. In addition, BMD systems are impossible to test under realistic conditions—actual nuclear war. Jerome Wiesner, science advisor to President Kennedy and later president of M.I.T., expressed these concerns in 1969. He said there was "no basis for confidence [that] most or many of the ABMs deployed will in fact intercept incoming missiles."

The fundamental political arguments against BMD have also remained the same. Suppose effective—and expensive—BMD could eliminate the threat of intercontinental ballistic missiles. It would still be unlikely to induce nations to give up their *motivations* for threatening to use nuclear weapons. Contending nations would seek out weapons not neutralized by BMD, such as nuclear cruise missiles, nuclear warheads carried by torpedo, nuclear weapons exploded at sea to create huge tidal waves and innundate coastal cities, and nuclear "suitcase bombs" assembled in enemy cities from smuggled parts.

Imagine that BMD were installed and no countermeasures were implemented or new weapons deployed. That could happen only if the current atmosphere of fear and hostility eased, argue BMD opponents. This mutual understanding would also have made it possible for both sides to eliminate much of their offensive weaponry, achieving the same effect as a defense without the enormous expense.

President Reagan's call for a comprehensive research and development program on BMD did not channel weapons technologies in fundamentally new directions. Even with the ABM Treaty in place, the Department of Defense has continued to sponsor close to $1 billion a year of research on BMD-related technologies. In attempting to redirect U.S. nuclear policy, what President Reagan has done is to reopen the debate about nuclear deterrence.

No one really likes the idea of deterring nuclear war through the threat of retaliation. However, informed people disagree over whether mutual assured destruction is a necessary evil or one that can be eliminated through better technology and policy. As in the sixties, today's debate pits the technological optimists against the technological pessimists, the war-fighting theorists against the assured-destruction theorists, and those who tend to confrontation against those who tend to conciliation. □

*Herbert Lin, who received his doctorate in physics from M.I.T., is a visiting scholar in the Peace Studies Program at Cornell University.*

plained that our nation's scientists were chasing after the weapons of mass destruction because "the offense is sweet." But now strategic defense is au courant. Lasers have dazzle. Even the more pedestrian $C^3I$—command, control, communications, and intelligence—which is crucial to spotting attacking missiles and ordering the defense, has a fashionably McLuhanesque aura.

With the president's leadership, Defense Department officials have organized the Strategic Defense Initiative, a proposed five-year intensive research effort. However, no particular system has been singled out for deployment. The focus is on further research until we can be confident of a scheme that works, and no one is predicting just what that will be. As Teller puts it, "It will be something you have never heard of."

*CAROLYN MEINEL is a staff scientist at Analytic Decisions, Inc., a defense consulting firm based in Arlington, Va. She is also an officer and part owner of Analog Precision, Inc., in Tucson, Ariz., which designs control and communications systems primarily for industrial customers.*

## *Hans Bethe and Edward Teller debate ballistic-missile defense.*

*(Continued from page 39)*

president to detail plans for proceeding with ballistic-missile defense, is asking for \$20 billion for research and development between now and 1989. That is just the first phase. The actual procurement will come later, and as far as I can estimate, each of the methods that could be used would cost close to \$100 billion.

**TELLER:** Many of us disagree with some of the Fletcher committee's work: it has given us parts of plans, but not yet a really good plan. As for whether solids are vulnerable to x-rays, I cannot debate this issue because of the rules of secrecy.

But what are the alternatives to ballistic-missile defense? Can we reduce arms by agreement? Look at the agreements that exist, such as on chemical and biological warfare. There is no question about the yellow rain—evidence that the Soviets have killed at least 10,000 people in Laos, Cambodia, and Afghanistan with toxins. There was an outbreak of pulmonary anthrax near Sverdlovsk in the Soviet Union, which as far as I know can be explained only by Soviet preparation for biological warfare. They claim it was the relatively harmless intestinal anthrax, but when the United States asked to look, they did not let us.

**BETHE:** I don't know about the yellow rain, but some people are not convinced that it comes from chemical weapons. I don't know about the anthrax either, and the books are not closed because the Russians won't let us in. But as far as I am aware, treaties about nuclear weapons, which can be observed by satellites, have been kept conscientiously. The Standing Consultative Commission of the two superpowers meets periodically in Geneva to sort out any possible doubts about adherence to the treaties.

**TELLER:** I do know of violations of the missile treaties, which I am not allowed to mention.

**BETHE:** Of course the ABM treaty, which forbids further deployment of antiballistic missiles, will be broken if we proceed with Star Wars. And given the many devices contemplated, it would be almost impossible to draft an arms-control agreement on ballistic-missile defense—let alone come to terms on one. Without such an agreement, the uncertainty surrounding defense will make the worst-case analyses of the military on both sides still more extreme than now. Each side will prepare not for the likely attack from the other but for five times that. This will accelerate the arms race on the ground.

**TELLER:** As I mentioned, the Soviets are already pursuing an active ballistic-missile defense around Moscow and probably many other cities. We have indications that their research on defense is years ahead of ours. U.S. scientists learned things about ballistic-missile defense from Soviet scientists four or five years ago, which I am now not allowed to repeat to the public. Thus, I am not proposing something really new, but something that we have good evidence has been pursued by the Soviets. If we try to do similar things, they will protest, of course, but I don't think they will be frightened.

**BETHE:** Despite what Edward Teller says, we are talking about a technology that does not yet exist. I have no objection to quiet research in laboratories, trying to discover an idea that is better than those I have heard. If some idea is found for a feasible defense, if there are no good countermeasures, and if the defense is not more expensive than the offense, I would be very happy. But at this point I think it is foolhardy to enter a \$20 billion research and development program to be followed by much larger sums—hundreds of billions of dollars. For the time being, this would only exacerbate the competition between the two countries. Therefore, I hope the United States will not enter into this program but will only pursue small-scale research, costing perhaps \$20 million a year.

**TELLER:** I agree that the proposal to spend \$20 billion has no solid foundation. I have asked for \$300 million for the coming fiscal year; this much we know how to spend usefully. I would be very happy to be exceedingly quiet if only Hans Bethe would come and help, and thereby, even beyond contributing his own talents, provide an example to young people that we must search for a ballistic-missile defense. What I'm arguing for is that U.S., British, French, German, and Japanese scientists should join in an effort to solve this problem. Admittedly, it is difficult, but I claim that we have the beginnings of an answer. What scientists did once when we went to Los Alamos to win a war, we should repeat, perhaps on a smaller scale, to win a secure peace.

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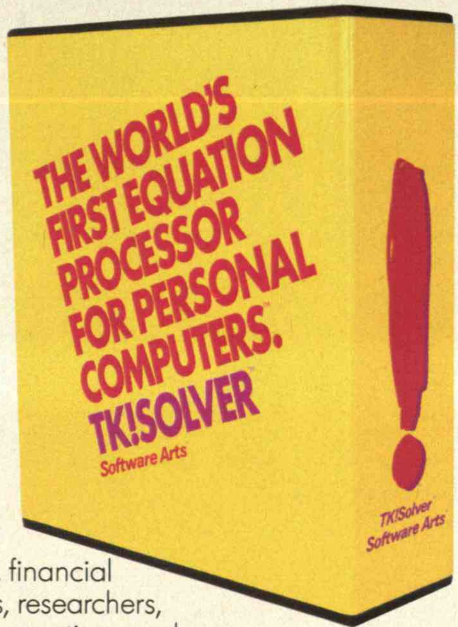


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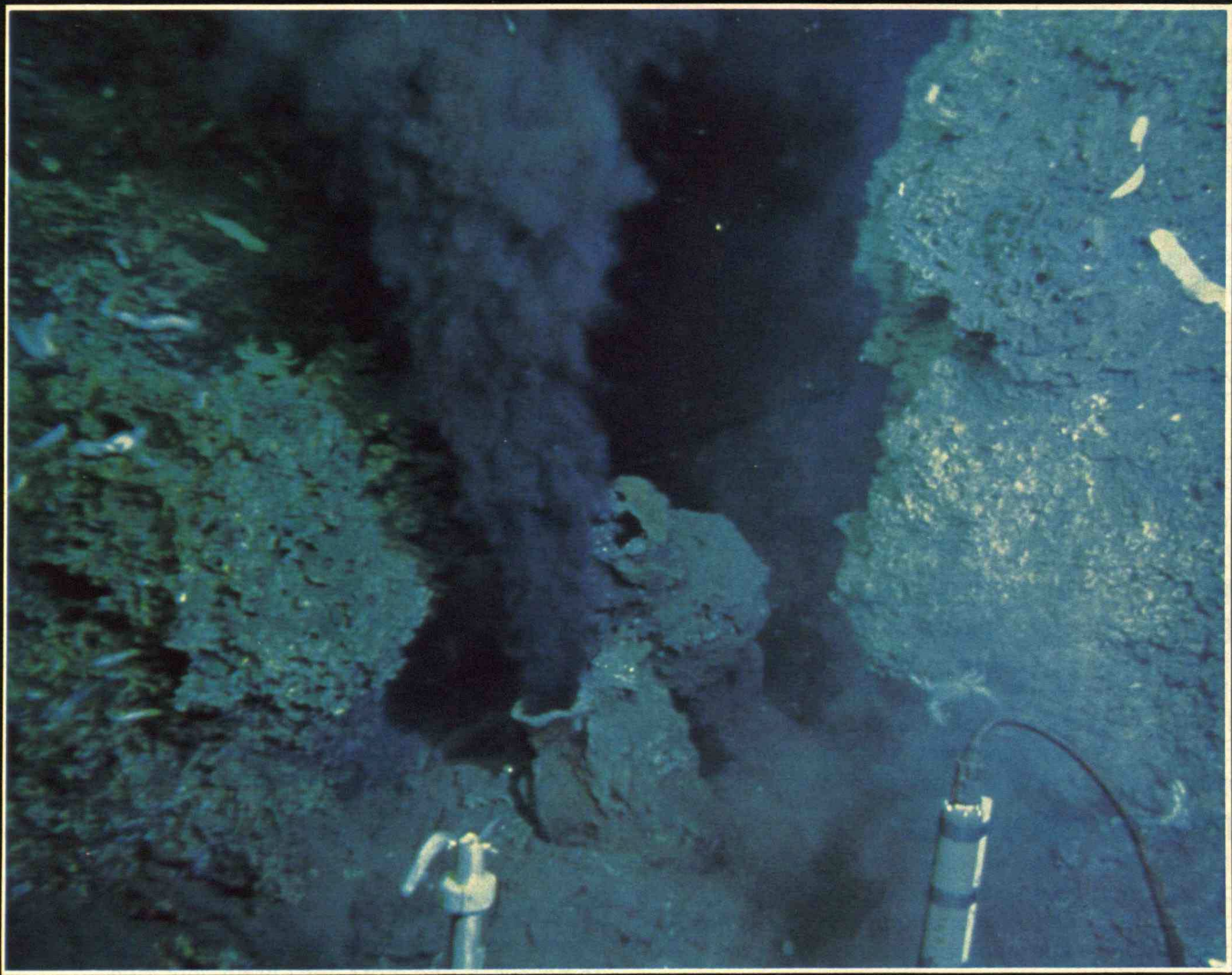


"Black smokers" serve as deep-sea metal smelters, carrying minerals such as zinc, copper, iron, and silver from the earth's interior. The smokers form "polymetallic-sulfide" deposits on the seabed, some larger than deposits now mined on land. U.S. government officials and many scientists tout the deposits as commercially attractive and want exploration to begin soon. Others, including mining-industry representatives, have serious doubts.

PHOTO: DUDLEY FOSTER, WOODS HOLE OCEANOGRAPHIC INSTITUTION

# Ocean Mining: Boom or Bust?

A piece of property with an unequaled sea view is scheduled to go on the auction block this fall, and whoever gets the lease may find a niche in history. Listed on maps as Gorda Ridge, this 180,000-square-kilometer parcel sits on the bottom of the Pacific Ocean, some 140 miles off the Oregon and northern California coast. The U.S. government thinks the area may be rich in the latest craze in geology—polymetallic sulfides, which are mineral deposits containing significant quantities of zinc, iron, and copper and lesser amounts of other metals such as silver, cadmium, chromium, and platinum. The Interior Department plans to lease ten tracts on Gorda Ridge to mining companies, who would explore the depths to determine what's really there and whether the mineral deposits can be exploited commercially.

This is "the first time the government has taken practical measures" to encourage mining of deep-sea minerals, according to Harold E. Doley, former director of the Interior Department's Minerals Management Service. Gorda Ridge won this distinction because of its location—it is entirely within the recently established U.S. Exclusive Economic Zone (EEZ). The EEZ extends the nation's jurisdiction to include all mineral resources within 200 nautical miles of the U.S. coast and its island territories. Some scientists, government officials, and industry representatives envision Gorda Ridge as only the beginning of an effort to harvest deep-seabed minerals. Others are more cautious, even pessimistic.

This difference in outlook was clearly evident at a symposium held last November, billed by its sponsors—the U.S. Geological Survey (USGS), Minerals Management Service (MMS), and the Bureau of Mines—as a meeting to "set priorities for the assessment and development of minerals within the EEZ." W. Perry Pendley, Interior's assistant secretary for energy and minerals, kicked things off by saying, "Today marks the beginning of a new phase in the EEZ—a phase of action." Pendley pictured the EEZ as "an enormous new frontier that is still largely unexplored in terms of the abundance and recoverability of mineral resources." And he declared: "You are the pioneers—the Neil Armstrongs, the Henry Comstocks, the John Wesley Powells . . . You will collectively shape the emerging path of progress in the EEZ."

While many participants seemed ready to accept that honor, many more brought the tone of the symposium back down to the bottom line. For example, David Stang, a consultant to the mining industry who headed a workshop on leasing issues, said, "If the government wishes to see polymetallic sulfides developed, it is going to have to do one of two things. It will have to do the exploration work through its own agencies, funded with taxpayers' money. Or it will have to provide sufficient economic inducement for industry to take those steps, if the interest is in having exploration done before normal marketplace opportunities would encourage such development." T.S. Ary, president of the Mineral Exploratory Division of Kerr-McGee Corp., was even more blunt: "The fair market value of a dream is zero."

BY TOM BURROUGHS

We may be on the verge of tapping Davy Jones' real treasure—valuable ore deposits on the seabed created by hot springs. But it won't be easy and may not pan out for several decades.

**The Reagan administration sees an important role for seabed minerals in maintaining national security. The United States now imports many strategic metals widely used in military and vital civilian technologies. For example, 900 pounds of cobalt are needed to produce the engine (inset) for this air force F-16 fighter plane—yet there are no domestic sources of cobalt.**

### Sulfides and Seamounts

Polymetallic-sulfide deposits are formed by hot springs that arise at seafloor "spreading centers"—mid-ocean ridges where molten rock rising from the earth's interior forms new crust. (*See "Metals in the Sea," page 61.*) Since these hot springs were discovered in the late-1970s, scientists have located polymetallic-sulfide deposits at numerous sites along the ridges. Some deposits are estimated to be larger than major ore deposits now being mined on land.

But while polymetallic sulfides have galvanized recent interest in ocean mining, the EEZ includes other commercial possibilities as well. "There are deep-sea features and mineral deposits that may prove as important or more important," Robert Ballard, senior scientist at Woods Hole Oceanographic Institution and a pioneer in seafloor exploration, told the symposium. "What I have in mind are the cobalt-rich manganese crusts that geologists recently learned are fairly common on the underwater flanks of volcanic islands and seamounts in the Pacific."

Volcanic islands and seamounts, or volcanos that never broke the surface of the water, dot the Pacific Ocean. Many of the islands—including Hawaii, Samoa, Guam, the Midway Islands, and the Northern Mariana Islands—are U.S. territories or possessions, and thus their adjacent waters are part of the EEZ. In 1982, a team of American and German scientists found that the sides of some Pacific seamounts were covered with a thin crust. Samples of dredged crust contained significant quantities of manganese, cobalt, and nickel. The scientists reported that each seamount "averaged 300 square kilometers and could yield several million tons of ore."

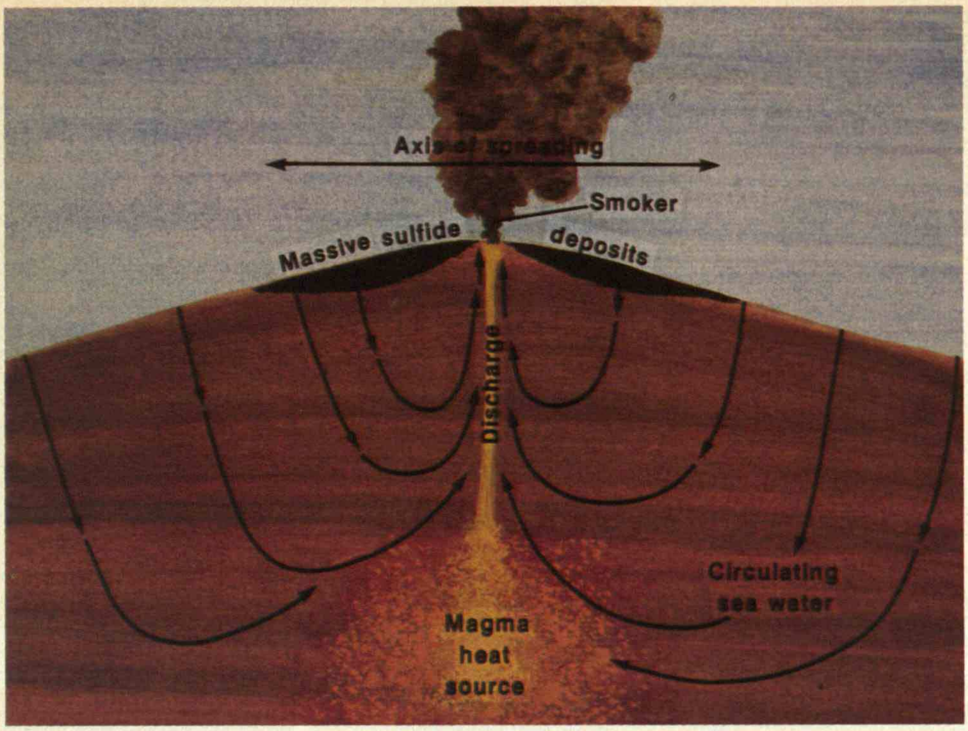
Researchers from the University of Hawaii have determined that offshore slopes around the Hawaiian Islands have similar mineral-laden crusts. And last summer, USGS scientists aboard the research vessel *S.P. Lee* made the richest finds yet while studying seamounts located between Hawaii and American Samoa. For example, crusts dredged from a seamount located about 160 miles northwest of Palmyra Atoll and Kingman Reef contained 32 percent manganese, 2.5 percent cobalt, and 0.8 percent nickel. Most seamounts probably won't be quite as rich, according to USGS expedition leader Frank Manheim. "For example, I think most crusts will average about 1 percent cobalt, but even this concentration is twice as high as in most deposits on land." Studying these seamounts and islands, let alone mining them, is difficult. Their underwater flanks are steep, with some at an angle of 45 degrees, and the metal-bearing crusts lie between 3,000 and 12,000 feet below sea level. Still, David Russell, acting director of MMS, said at the EEZ symposium that his agency was "making plans for lease offerings" for seamounts near the Hawaiian Islands.

### National Priority

Seabed deposits fit directly into the current administration's plans: "It is the policy of this administration," President Reagan has made clear, "to decrease America's minerals vulnerability." In April 1982, the United States voted against the Law of the Sea Treaty, which had reached its final session after ten years of discussion. "The deep-seabed-mining part



PHOTOS: PRATT & WHITNEY AIRCRAFT




**Cold seawater seeps down through cracks near the mid-ocean ridges. Molten rock heats the water, which dissolves various minerals in the crust. The water becomes buoyant as it gets hotter, finally rushing back to the surface. There the minerals precipitate out, some forming local sulfide deposits and some mixing with seawater and drifting away. The entire ocean passes through these vent systems about every 10 million years. In this way, hot springs contribute as much to the ocean's chemistry as do all the world's rivers.**

of the convention does not meet U.S. objectives," Reagan said. And then on March 10, 1983, he issued a proclamation establishing the EEZ. With the stroke of a pen, he quadrupled the ocean area over which the United States exercises jurisdiction—making it the largest such area under any nation's control. The new EEZ encompasses nearly 4 billion acres; by contrast, the onshore area of the United States and its territories totals only 2.3 billion acres.

At last November's symposium, Interior's Pendley stressed what the government sees as the importance of the EEZ in national security. "Our dependence on certain imported minerals is irrefutable," he said. For example, cobalt is not mined domestically—the nation's entire supply is imported, primarily from southern Africa. Some nickel is mined domestically, but more than 80 percent is imported. And nearly all supplies of manganese originate in central and southern Africa. Yet, said Pendley, "these special-property minerals form the basis of many technologies in the area of defense, energy, and space programs. Manganese is fundamental to the production of virtually all steels and most cast irons. Cobalt is vital for providing high heat and wear resistance to superalloys used in jet-engine parts. And nickel, which makes alloys resist corrosion, is widespread in its use for aircraft and shipbuilding."

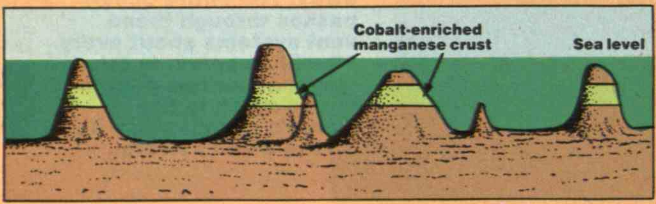
By contrast, the Soviet Union has reached self-sufficiency in supplies of most strategic materials, and has secure sources for the remaining few. Pendley hinted strongly at the possibility that the Soviet Union might engage in a "resource war," disrupting world markets and limiting the availability of strategic minerals. "The strategic importance of deep-sea minerals is not lost on the Soviet Bloc," he said.

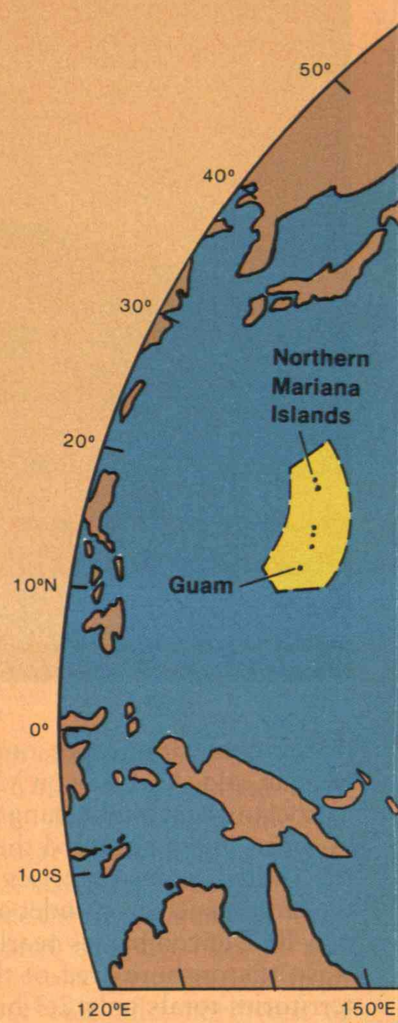
Thus, when it comes to exploiting the EEZ, Pendley affirmed that "we are supported by the national priority placed on our endeavor." For Gorda Ridge, this endeavor began on March 28, 1983, when the MMS published in the Federal Register its intent to prepare an environmental impact statement prior to leasing. The MMS completed a draft impact statement in late 1983, and distributed the document to state officials, environmentalists, and other groups. Public hearings were held in mid-February of this year in Coos Bay, Ore., and Eureka, Calif., but rumblings of discontent began even earlier.

Some critics, for example, have questioned how the MMS could have completed an adequate impact statement so quickly. Little is known about the underwater parcel being leased, and the necessary mining technology has not been developed. Federal officials admit to a dearth of specific information on the project, but they say that problem will be solved when someone gets out there and makes detailed explorations. The draft impact statement mainly describes the area to be leased, outlines what activities will likely occur, and lists the kinds of economic, social, and environmental effects that must be examined. Reid Stone, associate director of the Office of Critical and Strategic Materials, told *Oceans* magazine that "information will be the by-product rather than the foundation" of leasing. However, he added that more environmental impact statements will be prepared during the exploration phases before the federal government gives final approval. "Development will not occur," he said, "unless it can be done in an environmentally safe manner."

DIAGRAM: U.S. GEOLOGICAL SURVEY

**The Exclusive Economic Zone (EEZ) brings under the American flag all mineral resources within 200 nautical miles of the U.S. coast and its island territories (see map). While discovery of polymetallic sulfides has galvanized interest in deep-sea mining, the EEZ holds other prospects as well. The flanks of volcanic islands and seamounts—volcanos beneath the water's surface—are partially covered with a thin, metal-rich crust (bottom). Right: geologists use a chain dredge to sample the crust—richer in cobalt than deposits on land.**



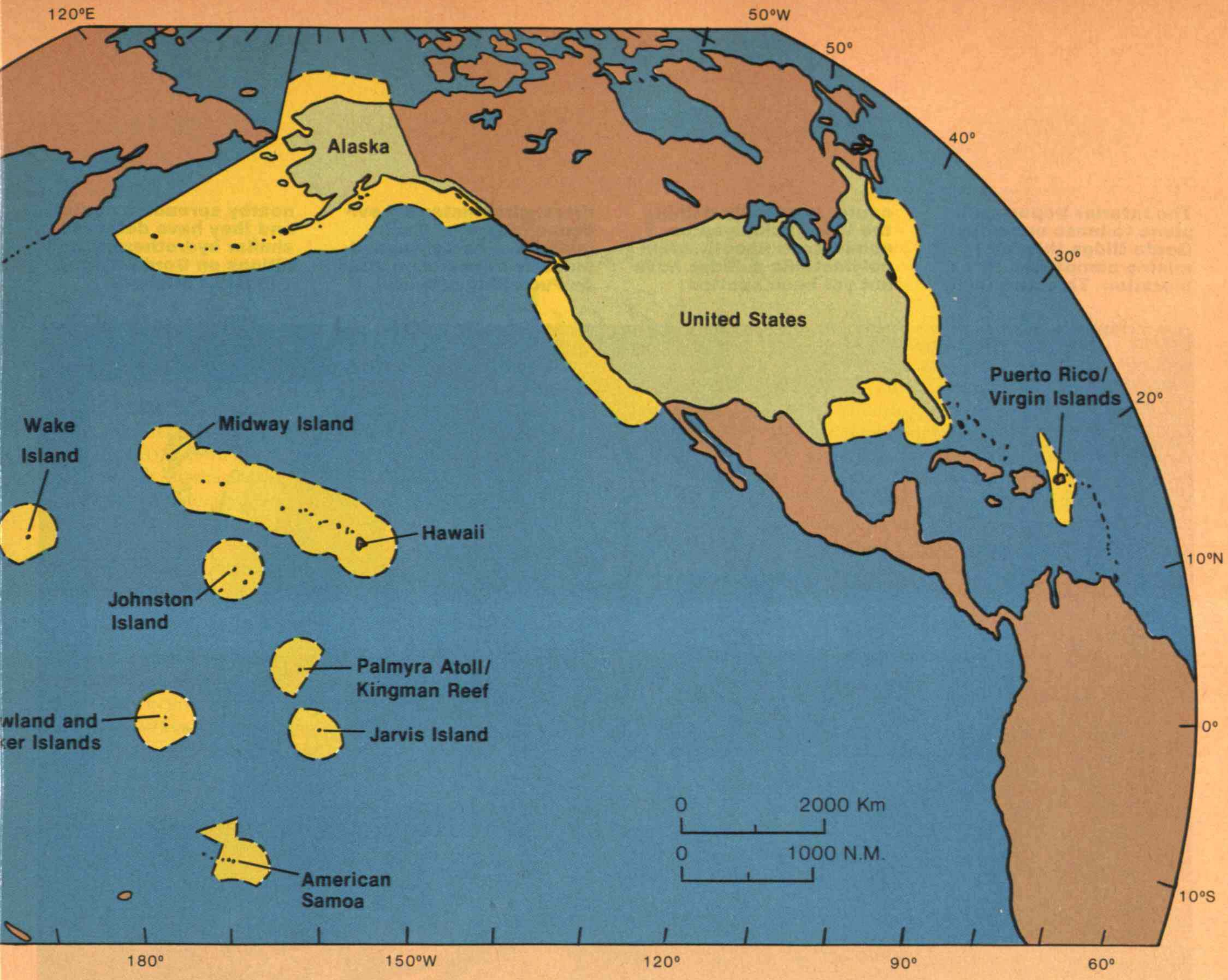

Other critics have claimed that industry is pushing the government to offer leases for Gorda Ridge. But federal officials don't see themselves as pushed; if anything, they feel the opposite. "If we don't offer tracts for lease, it may be a long time before industry becomes interested on its own," according to Fred Jacobs of the MMS. It's a matter of putting a carrot, not the cart, before the horse.

Firms bidding on the parcel will face many unknowns—the greatest being that no one is even sure whether Gorda Ridge has polymetallic-sulfide deposits. USGS scientists have discovered hot springs and sulfide deposits on Juan de Fuca Ridge, another seafloor spreading center just to the northwest but outside the EEZ. And since Gorda Ridge is geologically similar to Juan de Fuca Ridge and other spreading centers known to have such deposits, the government is assuming that the lease area will be so endowed. However, the agency's draft impact statement makes clear that "no estimates have been made on the total resource potential of the Gorda Ridge area." The MMS does assume that "sufficient quantities of polymetallic sulfides exist to warrant exploration," and that enough minerals "exist in commercially developable deposits to warrant multiple mining operations in the lease area."

## "It's Not an Ore"

Industry representatives aren't so sure about those assumptions. For example, after a USGS official at the symposium commented on the "fantastic potential of the ore deposits," a mining engineer in the audience broke in. "Look, we're using the wrong word," he said. "You people keep talking about 'ore.' Well, we don't know if it's an 'ore' yet, because we don't know what's down there. It's a beginning. It's a grand idea. But it's not ore—let's be real."

John E. Flipse, president of the Texas A&M Research Institute and someone long involved in deep-sea mining, also stressed the need to be practical. "When you're making a presentation to the board of directors," he said, "you've got to assign some kind of value to what is down there within the four




corners of the lease." He doubted whether a convincing economic argument could be made for bidding on the leases, especially given the mining industry's generally depressed conditions. "The miserable metals markets are still here," Flipse said. "Would you believe that the price of copper is the same today as it was in 1966," while all other costs in the mining industry have risen considerably? Other participants noted that zinc, which is often the predominant mineral in the polymetallic-sulfide deposits, is already abundant on land. However, MMS officials countered by saying that it will be more than a decade before full-scale mining can take place, even if exploratory leases are granted now. "By then," said Michael Cruickshank, "the metals market may be more favorable and the technology more advanced, and there may be a greater need for additional domestic supplies of these minerals."

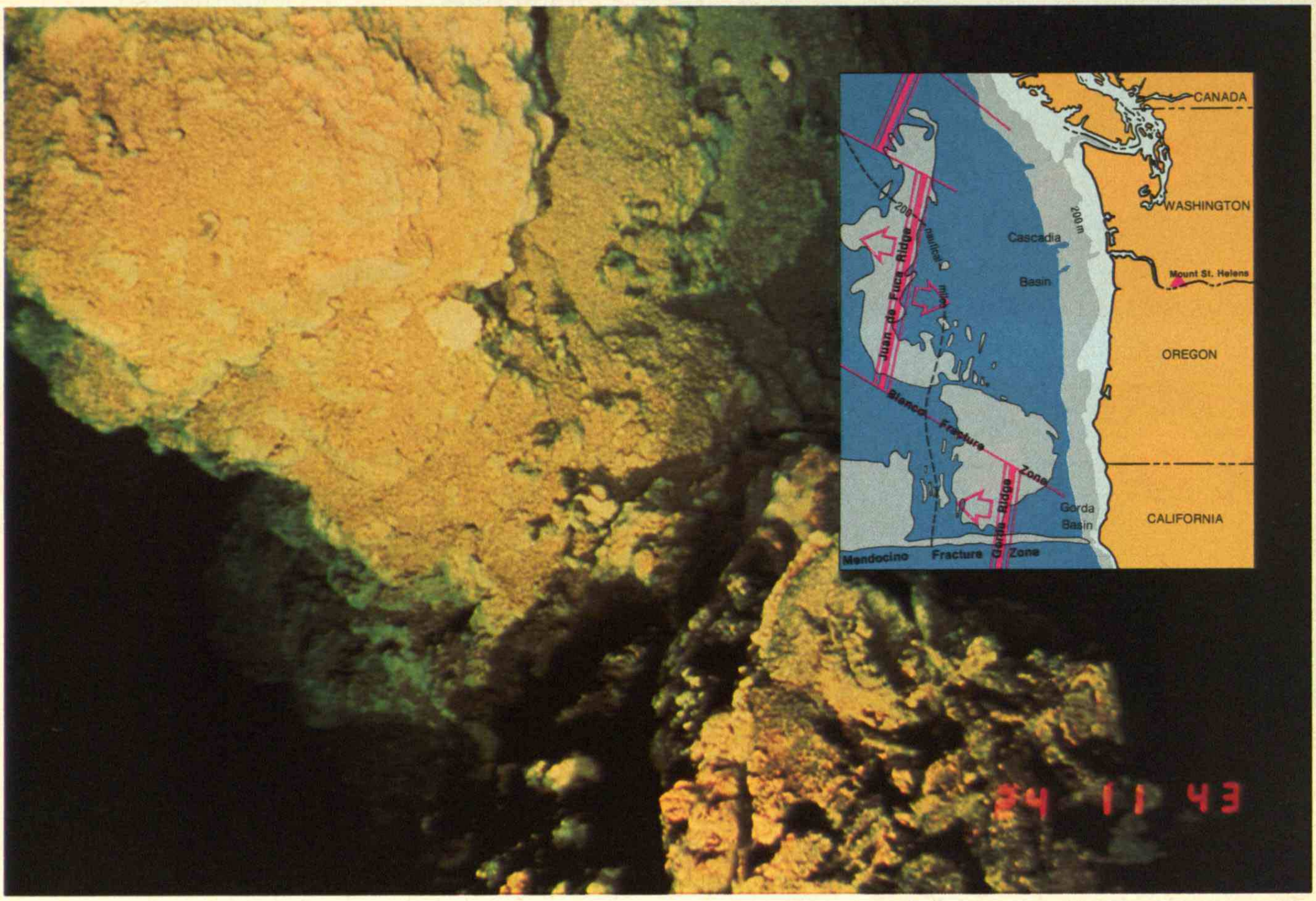
Robert Ballard of Woods Hole agreed that most of the polymetallic-sulfide deposits identified so far are "marginal in value." But he said that's at least partly because expeditions have focused primarily on basic scientific questions and haven't looked specifically for minerals. Members of Ballard's workshop concluded that the federal government must coordinate a national program combining the efforts of scientists from industry, universities, and government agencies. "We should let interest in exploiting minerals in the EEZ guide our short-term efforts," Ballard said, "but should not lose sight of the longer-term goal of assessing the potential of the entire ocean basin."

While this smacks of the typical committee recommendation, Ballard stressed that recent history shows the need for pulling together. In the early 1970s, no one challenged the U.S. lead in deep-sea technology. "We were the only nation that could routinely place scientific explorers in the deep abyss . . . and our scientists dominated research while other nations looked on with envy," he recalled. "All this has changed. First France, then England, then Germany, and now Japan and Canada have passed us in the area of deep-sea mineral exploration."

The reason, he said, is that the other nations have

MAPS: USGS; PHOTOS: FRANK MANHEIM, USGS

The Interior Department plans to lease undersea Gorda Ridge this fall to mining companies for exploration. This spreading center is entirely within the U.S. Exclusive Economic Zone (inset). While polymetallic sulfides have not yet been spotted there, circumstantial evidence is strong. Geologists have photographed massive deposits on Juan de Fuca Ridge (below), a nearby spreading center, and they have detected similar hydrothermal conditions on Gorda Ridge, 140 miles offshore.




encouraged their industries to participate, while U.S. industries have stayed on the sidelines. "While our scientists were forced to justify exploration for mineral deposits purely on scientific grounds, France organized cruises focused on the commercial potential of these deposits," Ballard noted. "While we added basic researchers in biology and chemistry to our teams, they added mining engineers and economic geologists to theirs." And he posed the question: "Why can't U.S. industries contribute to a national program the way Canadian industries do?"

They might, was the general answer, if conditions were right. For example, several industry representatives said that any company obtaining a lease should be able to follow through to exploitation without worry that the government might change its mind about allowing such a move. "Once we've sunk money into exploration and know what's out there," said Kerr-McGee's Ary, "we want to be able to go ahead." However, MMS officials didn't think such an open-ended plan was possible and stressed the need for several check-off points along the way. For example, updated environmental impact statements might require changes in the course of development.

The USGS has likened President Reagan's proclamation of the EEZ to the Louisiana Purchase of 1803, which doubled the nation's area by extending its border west to the Rocky Mountains. "The challenge of exploring the EEZ is as great as any faced by the early explorers who opened up the nation's onshore territories," Interior's Pendley told the symposium. But many of the would-be explorers he faced seemed more concerned with the cost of the journey and whether going first was worth the risk.

*TOM BURROUGHS is a senior editor of* Technology Review.



PHOTO: WILLIAM R. NORMARK, USGS; MAP: USGS

# Metals in the Sea

BY ROBERT COOKE

*Using deep-diving research submarines to explore seafloor "spreading centers," scientists have obtained their first look ever at ore deposits in the process of forming.*

"THE most exciting development in oceanography in recent years has been the discovery and systematic sampling of ocean hot springs," declares John M. Edmond, professor of earth and planetary sciences at M.I.T. Diving to ocean depths of 9,000 feet or more in high-tech research submarines, scientists have explored tremendously active zones where superheated water spews violently through vents in the seafloor. The springs, carrying metal-rich water from inside the earth, offer the first view ever of ore deposits in the process of forming. Indeed, the seafloor has become a tantalizing new frontier—a difficult but promising province where crucial minerals abound.

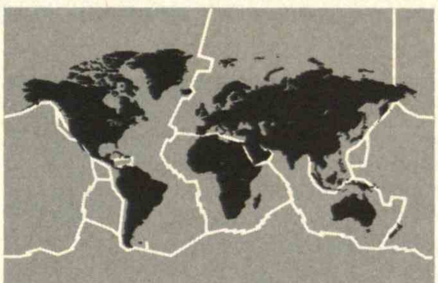
The story begins with "plate tectonics." By the mid-1960s, geologists had generally accepted the idea that the earth's crust consists of a dozen major plates that are continually bumping and scraping against one another. Seafloor spreading is a key element in this scenario: hot magma from inside the earth wells up along mid-ocean ridges, cools, and forms new crust that becomes part of the moving plates.

However, many details remained unclear. One mystery involved the flow of heat: rock near the mid-ocean ridges wasn't as hot as scientists expected. They theorized that cold seawater might be penetrating the crust, picking up heat from the magma, and returning to the sea as hot springs. But they had no direct evidence.

**Down to the Depths**

Then, in 1977, scientists from Woods Hole Oceanographic Institution, Oregon State University, and the Scripps Institution of Oceanography joined together to study a section of mid-ocean ridge called the Galapagos Rift. Located in the Pacific Ocean some 240 miles east of the Galapagos Islands, this rift is a branch of a long spreading zone called the East Pacific Rise.

They first towed electronic thermometers along the ridge—nearly 8,000 feet deep—and did indeed find some spots where water temperature was a fraction of a degree higher than the ambient, near-freezing seawater. Next, they towed *Angus*, a camera-equipped sled with temperature sensors, along the ridge. *Angus*, too, found warm spots, but even more remarkable, it spotted a bed of giant white clams, surely evidence that the water must be warm.



Winding some 42,000 miles around the globe, the mid-ocean ridges outline the earth's major plates. Hot springs seem commonplace along the ridges, where new ocean crust is constantly being formed.

MAP: OMNIGRAPHICS

Finally, two scientists—Edmond and Jack Corliss of Oregon State University—plunged to the bottom in a tiny submersible called *Alvin*. Edmond remembers: "After driving around on the sea floor for half an hour or so trying to locate the target, we stopped to collect some rocks. As the pilot wrestled with the basalt using the submarine's electric arm, a couple of large, purple sea anemones engaged our attention. Only when focusing back from these did we realize that the water was shimmering. The hastily measured temperature was 5° above the ambient water temperature.

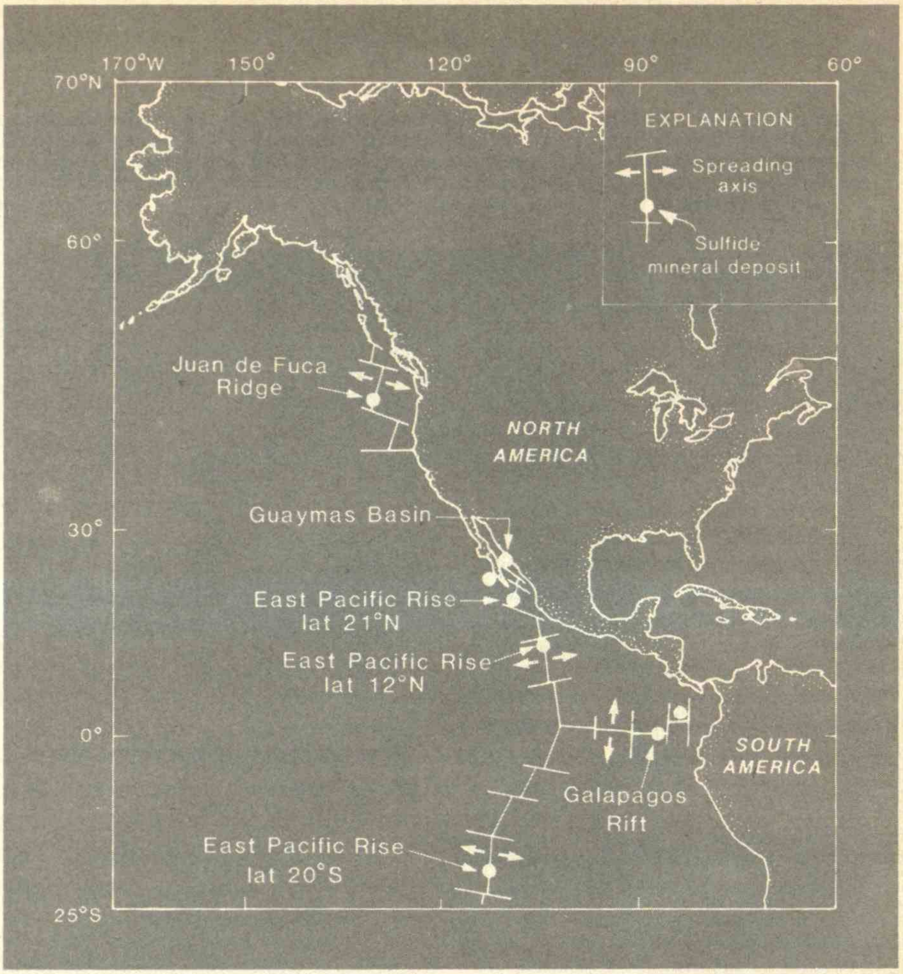
"With all thoughts of rock forgotten," says Edmond, "we sampled this water and continued on our course up the ridge slope. Here we came upon the most fabulous scene . . . an oasis! Reefs of mussels, fields of giant clams, crabs, anemones, and large pink fish were all bathed in shimmering water." They had, at long last, found a field of hot springs.

Other scientists later rode *Alvin* down to the ridge, collecting samples of water, rock, and organisms. (Indeed, the unexpected and unusual biotic community caused its own scientific stir. The area turns out to be home to an entire ecosystem supported by geothermal energy rather than sunlight.) Back in the laboratory, Edmond says they finally concluded that the water in the vents must reach at least 350° Centigrade—hot enough to melt lead—though *Alvin*'s sensors registered a high of only 19° C. Could this be true?

**Deep-Sea Smelters**

In 1978, a team of French, American, and Mexican scientists used the French submersible *Cyana* to explore another site on the East Pacific Rise. The site is off Baja California and is called 21° North, prosaically named after its latitude. There the searchers found extinct hydrothermal vents and colonies of dead clams. But the big event came in 1979, when the international team returned to 21° North. Expedition leader Robert Ballard of Woods Hole, a pioneer in this field, described a dive in the book *Exploring Our Living Planet*: "We found not only a similar biological community, but also 'black smokers,' tall stony chimneys in the middle of the oasis, with opaque clouds of black water jetting straight up from them. They

*"The most exciting development in oceanography in recent years has been the discovery and systematic sampling of ocean hot springs."*




looked like the steel plants of yesteryear."

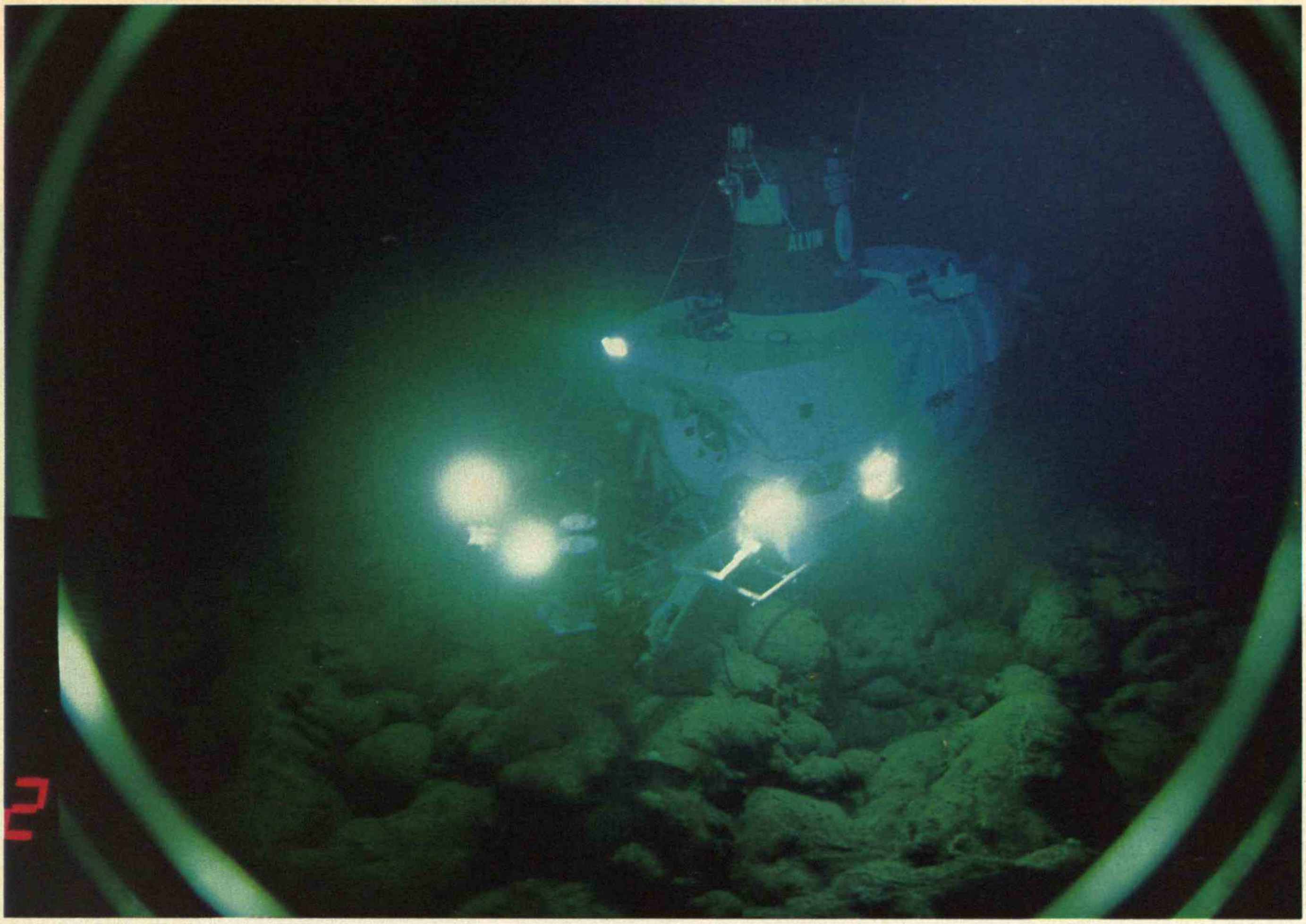
The updraft of water gently pulled *Alvin* closer. "Luckily, we were able to keep our distance," Ballard noted, "for when we inserted a temperature probe in one chimney, the instrument melted, though it was made of the same tough plastic as *Alvin*'s viewports." Later measurements revealed the jet of water to be 350° C. The plumes of water looked dark, it turned out, because they contained significant amounts of dissolved minerals, including iron, copper, zinc, and silver.

*Alvin* even nudged over some of the chimneys and brought up samples, which proved to be incredibly rich in minerals. Indeed, most of the seabed along the ridge was layered with ore deposits. "To dive on one of these hydrothermal sites," says geophysicist Peter Rona of the National Oceanic and Atmospheric Administration (NOAA), "is really the fulfillment of a geologist's dream—to actually see mineral deposits being formed."

The picture thus became clear. Cold seawater percolates down through cracks in the crust near the ridge. Magma, which is fairly near the surface at spreading centers, heats the seawater. The hot water readily dissolves various metals and sulfur from the rocks through which it passes. As it gets hotter and hotter, the water becomes increasingly buoyant. The superheated water eventually surges back to the surface, emerging in geysers and carrying along a cargo of dissolved minerals. When this water suddenly meets the near-freezing seawater, the minerals precipitate out in the form of metal sulfides—iron sulfide, zinc sulfide, and so on—and these build up to form the chimneys and surrounding "polymetallic-sulfide" deposits.

Hot springs and polymetallic-sulfide deposits have now been found at many other sites along the mid-ocean ridges. For example, the American-French team, diving on the East Pacific Rise at a site called 12° North, found black smokers in almost continuous activity along 11 miles of the ridge crest. And Peter Lonsdale of the Scripps Oceanographic Institution has explored an unusual cluster of hot springs—complete with huge mounds of ore and spectacular colonies of living organisms—in the Guaymas Basin in the Gulf of California. Here, the East Pacific Rise is actively rifting the Baja Peninsula away from the mainland. Being close to land, this spreading center is continually buried by sediments coming in from rivers, so conditions are markedly different from those at other deep-sea vents. "The sediment acts as a trap," says Edmond, who has also dived at the site. "The whole sediment column is mineralized to produce large ore deposits of the 'Besshi' type, named after a well-known example of such a deposit mined in Japan."

Alexander Malahoff, chief scientist for NOAA's National Ocean Survey, located a huge field of extinct hot springs on the Galapagos Rift—just a short distance from the site of the first discovery—that had left behind tremendous polymetallic-sulfide deposits. Traveling in *Alvin*, he measured the deposit to be more than a half-mile long, 650 feet wide, and at least 115 feet thick. The ore, he reported in *Sea Technology*, "consists on the average of 7 percent copper, 32 percent iron, 40 percent sulfur, 1.3 percent zinc, up to 440 parts per million cobalt and 360 parts per million selenium, and smaller traces of the platinum group of metals." He has estimated that the area might contain 25 million tons of copper and zinc, an amount larger than some major ore deposits now



being mined on land. M.I.T's Edmond says such a deposit "would certainly be exploited" if it occurred on land.

In September 1981, scientists from the U.S. Geological Survey and the University of Washington located hydrothermal vents and polymetallic-sulfide deposits on the southern end of the Juan de Fuca Ridge, located about 250 miles off Oregon. The scientists estimated then that "approximately 250,000 metric tons of zinc- and silver-rich sulfide may lie within the study area." However, underwater photographs and dredged samples obtained during expeditions last summer suggest that the deposits are much larger and may contain "four times" the total amount of minerals originally estimated. "We know that the individual polymetallic-sulfide deposits are longer and wider than we thought," Survey scientist David Clague reported at a mid-February meeting on deep-sea minerals sponsored by the Interior Department. "But we still don't know how thick they are, and that must be determined before estimates about the resource can be made with real confidence. Clearly, though, there could be a lot there."

**Moving slowly along a mid-ocean ridge some 8,000 feet deep, *Alvin* visits an eerie realm only imagined a decade ago. Scientists discovered the first hot springs in 1977 near the Galapagos Rift, a spreading center near the Galapagos Islands. Since then, they have explored hot springs—and found ore deposits—at numerous sites in the Pacific (map, opposite page). *Alvin*'s claw arm brought up this sample from the wall of a black smoker. It consists of zinc sulfide and glistening copper-iron sulfide, both commercially important ores.**

MAP: USGS; PHOTOS: ALVIN CHANDLER AND EMORY KRISTOF, NATIONAL GEOGRAPHIC SOCIETY

**Left:**
**Cramped inside *Alvin*, pairs of scientists take turns exploring the hot springs. The first temperature probe inserted into a "black smoker" melted (bottom). Later measurements revealed the jet of water to be at least 350° C.**

**Above:**
**Foot-long clams, ghostly crabs, and other exotic creatures thrive around hot springs. Discovery of this complex ecosystem excited biologists: it is the only known ecosystem not based on sunlight. Instead, the organisms rely on heat and minerals from the earth's interior.**



PHOTOS: EMORY KRISTOF, NATIONAL GEOGRAPHIC SOCIETY; WOODS HOLE

U.S. and Canadian scientists have also discovered significant polymetallic-sulfide deposits on the northern reaches of the Juan de Fuca Ridge. And to the southeast of Juan de Fuca, within the recently enacted U.S. Exclusive Economic Zone, geologists have located another ridge system that they believe has abundant polymetallic-sulfide deposits. Indeed, this fall the federal government is expected to start leasing this region, called Gorda Ridge, to mining companies for exploration.

**Potential, but Also Problems**

Lest prospectors and speculators get too excited, opinion varies widely about how soon—or even whether—polymetallic-sulfide deposits will be exploited. Edmond warns that mining the deposits found thus far would "probably be uneconomical" at foreseeable prices of metals, given the availability of metal-rich ores on land and the primitive nature of deep-sea mining technology. He maintains that the government is trying to "hype this seabed hydrothermal thing into a resource." But he sees too many problems: the deposits are in very rugged topography and—though composed of rich ores—they are often relatively small.

Another stumbling block is the current confusion over property rights. Most of the deposits are in international waters, unaffected by any nation's territorial claims. But the provisions of the Law of the Sea Treaty would presumably apply, even though the United States has refused to sign it, and the risk for U.S. investors under these conditions would be very high.

On a more positive note, Robert Ballard of Woods Hole points out that research, which has rapidly yielded spectacular discoveries, is only beginning. "A few years ago we didn't know any of this existed," he says. "But now, all of a sudden, after detailed exploration of only a small sample of the seafloor, the whole picture has changed." Less than 100 miles of the mid-ocean ridge system—which winds for some 42,000 miles around the globe, rather like the seam on a baseball—has been explored. "This means we may be in for a period of major discoveries of heavy metals in the deep sea," Ballard says. "If the last few years have yielded this, then we can extrapolate that there's a hell of a lot more that we haven't seen."

Asked if he could estimate the amount

*Studying the hot springs and polymetallic-sulfide deposits will provide important clues in the search for ore bodies on land.*

of ore available on the seafloor, Ballard warns that "we're working with pretty flimsy data." Still, he says, the creation of the vent systems that lay down ore "is pretty well keyed to the spreading rate" at the mid-ocean ridges. The hot springs seem to "turn on" once the seafloor spreading rate reaches 6 centimeters per year, and Ballard says about 60 percent of the entire mid-ocean ridge system is spreading at least that fast.

NOAA's Malahoff also notes that polymetallic-sulfide deposits are found at depths about "one-half the depth of manganese nodules," which were previously the major candidate for large-scale deep-sea mining. Still, he says new technology will be required, as recovery systems designed for vacuuming or dredging manganese nodules off the seafloor won't be suitable for exploiting the sulfide ores.

"The sulfide deposits are found in very local but dense deposits that will require devices to ram or shatter the hard but brittle sulfides," Malahoff says. This may require construction of some form of "steady, stationary ocean-mining platform." Some researchers have also proposed using huge suction hoses to carry the dislodged ore in slurry form to waiting barges. The ore would then be hauled to holding and processing facilities onshore.

**Looking on Land**

Direct use of these deposits is only one of the ways they may be exploited, however. Edmond believes the findings should significantly improve our understanding of the location, history, and geochemistry of ore bodies found on land. "That's a much more exciting question," he says. "What you have on the continents are samples of seafloor, jammed up by plate tectonics, left over from the spreading centers. I'm really interested in knowing how these deposits form—under what conditions—and how they are changed before they emerge on land.

"Geologists who work for commercial mining companies call themselves 'prospectors,' " Edmond says. "They'll tell you a lot of it is hunch. But when these people see our slides of the seabed deposits they get very excited, because they don't generally get a chance to think in terms of how deposits actually form. They usually think about the end result, after the ore deposit has been metamorphosed and generally mangled." Until now, geologists considered almost every ore body unique, having formed under special circumstances. "But now that we have concrete examples of ore forming before our eyes," he says, "it throws out the window a lot of the speculation and the special cases."

Though debate about the commercial potential of deep-sea polymetallic-sulfide deposits continues, some scientists maintain that the United States is moving too slowly. The Interior Department's leasing of the Gorda Ridge planned for this fall is a step. But Ballard, for example, feels the federal government is still "sitting on its hands": much of what's going on now "is infighting over authority," he says, "with NOAA and the U.S. Geological Survey going at it."

The irony, Ballard says, is that the discovery of the sulfides is a product of investigations of the mid-ocean ridge sponsored by the National Science Foundation (NSF). "But the NSF feels the job is done, and that it's not in its charter to pursue this in a commercial way." Therefore, the scientists who were responsible for the discovery now have no way of pursuing the technology that would be needed to exploit it, short of forming their own consulting company. "Really ridiculous," he says. "Very frustrating."

Still, Ballard will spend much of this year at sea. For example, he will join with French scientists in using the submersible *Cyana* to explore the East Pacific Rise at a position known as 18° South, near Easter Island. The seafloor is spreading fastest at this site, roughly 18 centimeters each year, so Ballard says hydrothermal activity should be intense, with polymetallic sulfides forming in massive amounts. In August, he will board the U.S. Navy's nuclear-powered submarine *NR-1* to investigate a section of the mid-Atlantic ridge. The seafloor generally spreads more slowly in the Atlantic than in the Pacific, so there are likely to be fewer hydrothermal zones. But on the Reykjanes Ridge,

*Though debate about the commercial potential of deep-sea ore deposits continues, some observers maintain that the United States is moving too slowly.*

south of Iceland, spreading is faster, and the chance of finding active vents is considered good.

**Is the United States Falling Behind?**

Continued exploration of the seabed is the most immediate need, Ballard stresses, with the government helping to map the location of vent systems and polymetallic-sulfide deposits. He agrees that we shouldn't rush into large-scale mining operations, since the economics don't look favorable. "But the deposits are a new security blanket that we didn't know we had and that we ought to be ready to use," Ballard adds. "If shortages of metals develop, then we know where to go."

Ballard also notes that other countries are moving much faster. The French "have a massive sulfide-exploitation program, and they're dead serious," he says. And the German firm Preussag plans to begin commercial operations this summer in the Red Sea, mining mineral-rich sediments produced by hydrothermal vents in what's called the Atlantis II Deep. Preussag is doing the work for a group of nations that includes Saudi Arabia and the Sudan.

The group's prospects are good. In 1979, Preussag brought up 15,000 cubic meters of Red Sea sediment and used it to test a shipboard system for concentrating the ore and refining the metals. Zinc made up 40 percent of the resulting concentrate, accompanied by smaller proportions of silver, copper, and gold. "There's a gold bar and a silver bar sitting on a desk in Riyadh now," Ballard says. Indeed, the Canadian Department of Energy, Mines, and Resources places the total recoverable amounts from Red Sea deposits at 1.7 million metric tons of zinc, 400,000 tons of copper, and 5,000 tons of silver.

Not to be overlooked in the midst of commercializing these seabed resources, of course, is the scientific excitement concerning the hot springs and their role in global geologic processes. By studying these phenomena, geologists have gained insights into the way continents are being formed and destroyed. And geochemists like Edmond have discovered important clues about how the sea maintains its chemistry. Although scientists once assumed that all the minerals in seawater had to come from rivers running off the land, they knew that the quantities of elements in the ocean did not support that theory—for example, there was too much manganese and not enough magnesium. Edmond says that samples of the water from the vents have clarified the importance of these hydrothermal systems.

Globally, the water passing through the vent systems equals one half of one percent of the water entering from the world's rivers. This vent water picks up chemicals from the underlying rock, and leaves behind some of its own chemicals. "Although that may seem like a relatively small flow," Edmond says, "the actual transport of chemicals in these vents per liter of water is far higher because the chemicals are so concentrated. The overall effect, in terms of injection of chemicals into the ocean, is comparable to that from river flows." He notes, too, that a volume of water equal to the entire ocean will pass through the hydrothermal vent systems about every 10 million years. Thus, the sea may have been recycled 500 times in the earth's long history.

*ROBERT COOKE is science editor of the* Boston Globe.

**Confusion over property rights hinders deep-sea mining. The United States voted against the Law of the Sea Treaty on April 30, 1982, after ten years of discussion in the United Nations. While some deposits lie within the recently created U.S. Exclusive Economic Zone, many are in international waters, where risks may be unacceptably high for U.S. mining companies.**





PHOTO: UNITED NATIONS

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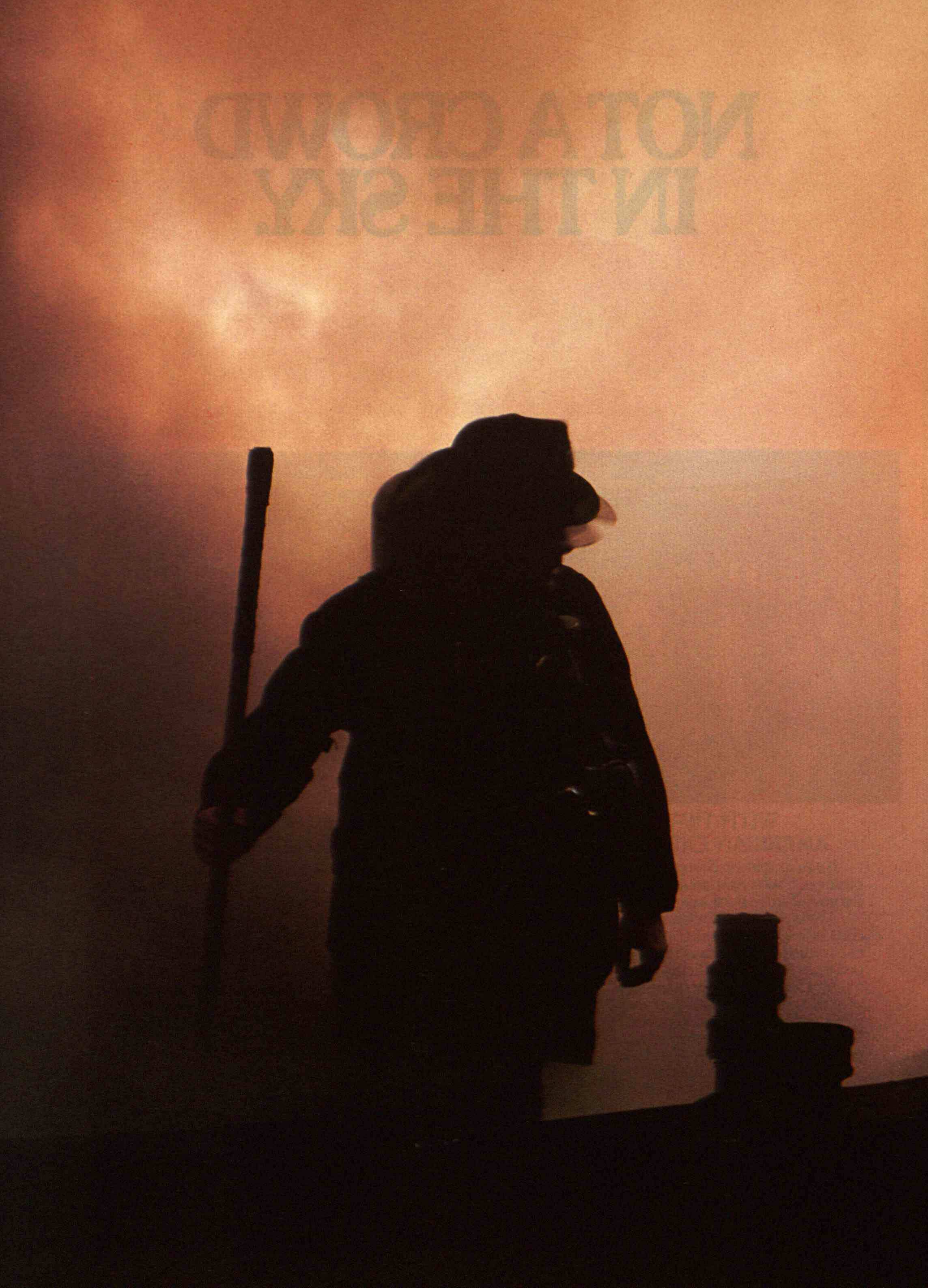


SMOKE TOXICOLOGY
A SPECIAL REPORT

# Where There's Smoke, There's Ire

*As synthetics increasingly replace natural materials in buildings, angry debate swirls around whether this heightens the danger of fires and whether anything can—or should—be done.*

BY LINDA GARMON

IN the early morning of March 6, 1982, fire broke out in room 404 of the Westchase Hilton Hotel in Houston. The presumed culprit: a carelessly placed cigarette. Local fire officials described it as a "simple room fire," and the deputy fire chief reported that extinguishing the blaze was a "fairly straightforward" operation. The room's occupants escaped unharmed. But ten other guests on the same floor died in their rooms from smoke inhalation.

Smoke—not flames—has for many years been recognized as the primary killer in fires. Of the roughly 7,500 fire fatalities in the United States each year, smoke fells more than 80 percent. Traditionally, nearly all smoke-inhalation deaths have been summarily attributed to carbon monoxide, a toxic gas produced during the combustion of essentially everything that burns. However, researchers from the Foundation for Fire Safety pieced together a different picture of the Westchase fire.

According to Merritt Birky, director of research at the foundation during the investigation, blood samples taken from the victims did show elevated levels of carbon monoxide, but they were not high enough to be the direct or sole cause of death. On the other hand, all the victims had elevated levels of hydrogen cyanide in their blood, and two had levels high enough to be lethal. The victims also had sustained severe respiratory damage, suggesting exposure to hydrogen-chloride gas.

These poisonous gases were generated by the combustion of synthetic materials in the room, says Birky. The foundation's tests indicated that the hydrogen cyanide came from polyurethane carpet padding, nylon carpet and blankets, and a polyurethane cushion on an upholstered chair.

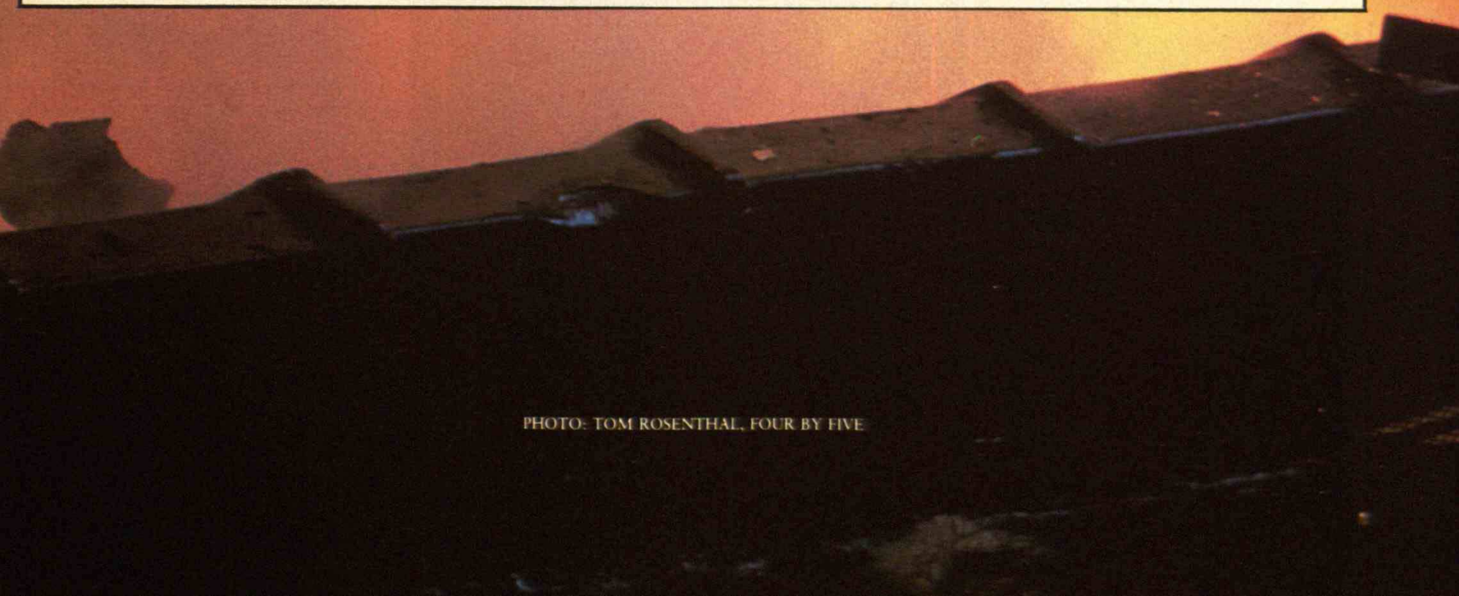
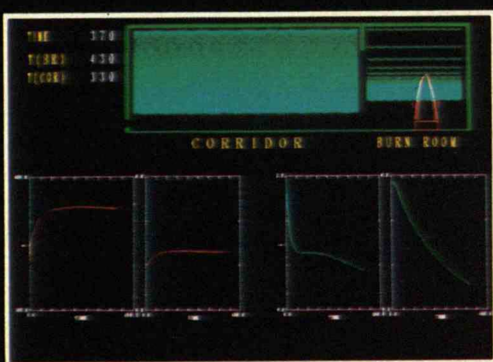
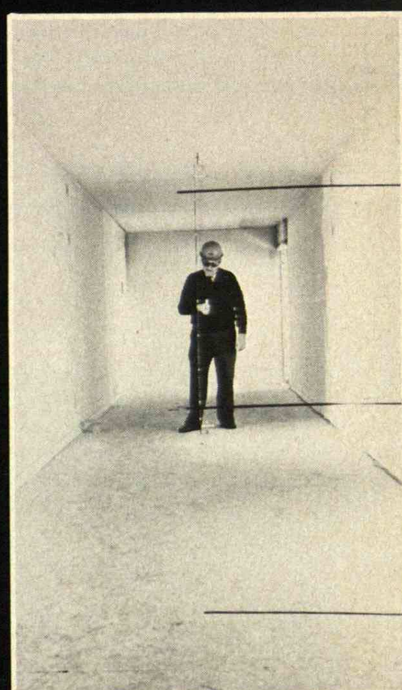


PHOTO: TOM ROSENTHAL, FOUR BY FIVE

**Eighty-three people died, most from inhaling smoke, in the 1980 Las Vegas MGM fire (top). Some observers say we can reduce such deaths now—for example, by establishing a combustion-toxicity data bank. Others claim we first need better hazard-assessment tests, such as a computerized method being developed at the National Bureau of Standards. The photographs left and right show how smoke from a "test burn" that quickly fills a corridor can be modeled on a computer screen above.**

*Smoke—
not flames—is the primary
killer in fires, and toxic gases generated
when synthetic materials burn
may be making smoke
even more deadly.*

The hydrogen chloride came from a polyvinyl-chloride wall covering. Birky says the study concluded that deadly gases from the burning synthetics "contributed to most, if not all," of the deaths.

Representatives of synthetics manufacturers have assailed Birky's conclusions. For example, John Lawrence of the Society of the Plastics Industry says, "There were a lot of synthetic materials in the room where the fire occurred, but there were a lot of burnable nonplastics, too." He notes that the Houston medical examiner listed inhalation of carbon monoxide and soot as the cause of death of every victim except for the people in one room, who had lethal levels of hydrogen cyanide in their blood. Even then, Lawrence says that blood-cyanide measurements are often suspect because the body itself produces some hydrogen cyanide. "We feel that plastics, where properly used, do not present any increased hazard," he concludes.

### Clash of Interests

The dispute over the Westchase Hilton tragedy is part of a larger, long-standing, and heated controversy in fire safety. There is no question that use of synthetics in buildings is rapidly increasing. "We live in a synthetic world," says Birky, where plastics and other synthetic materials have become commonplace in furnishings. Perhaps less visible is the growing role of synthetics in construction. In the mid-1960s, plastics represented only 2 percent of total building materials. By 1981, they had captured 10 percent of that market, according to Predicasts, a Cleveland market-research firm. And trends suggest that use of plastics may grow even more during the rest of the decade.

Has this shift heightened the danger of fires? Should the use of plastics and other synthetics somehow be regulated based on the toxicity of the smoke generated when they burn? Are laboratory tests well-enough developed to compare the smoke toxicities of various products, and to become the basis for selecting—and perhaps restricting—the use of furnishing and construction materials?

Answers to these questions have proved elusive, partly because combustion toxicology is a complex science, but also because huge economic stakes are involved and the issues have been clouded by corporate maneuverings and rhetoric. The most vociferous charges have been exchanged between the Society of the Plastics Industry (SPI), a trade association, and Allied Tube & Conduit Corp., which produces steel conduits used to contain and protect electrical wiring. Such conduits, along with pipes used in plumbing and to carry gas, have been one of the fastest growth areas for plastics in the U.S. construction industry.

Against this backdrop, an increasing number of toxicologists, legislators, and fire-safety officials has begun to sort through the tough regulatory and scientific issues. Indeed, the smoke-toxicity debate—which really gained steam during the widely publicized string of hotel fires starting with the Las Vegas MGM Grand Hotel disaster in 1980—has reached white-hot intensity.

Spurring the latest round is a report urging New York State to require manufacturers of building and furnishing materials to use a standard laboratory test to identify the poisonous gases generated when their products burn. The report, prepared by Arthur D. Little, a consulting firm based in Cambridge, Mass., recommends that such information on toxicity be filed in a central data bank. The New York Legislature, following the 1980 fire at Stouffer's Inn in Harrison, N.Y., which claimed 26 lives, had asked ADL to examine the feasibility of regulating smoke toxicity.

The fate of this proposal is still uncertain. New York Secretary of State Gail S. Shaffer is expected to recommend that the state establish a pilot program requiring manufacturers of mattresses, furniture, and interior finishings such as wall covering to test their products and submit the results to a data bank. However, she is expected to exclude construction materials.

Should New York adopt even this limited program—which is considered likely—it would be a landmark in fire-safety regulation. Of course, construction methods and materials are already subject to numerous other fire-safety-related regulations. A multitude of building-code provisions calls for fire alarm systems, fire doors, fire escapes, fire extinguishers, and exit corridors. And the Consumer Product Safety Commission has set mandatory flammability standards for mattresses and carpets and voluntary standards for upholstered furniture. But precious few codes, standards, or laws specifically address smoke toxicity.

One emerging code involves plastic conduit—a tube, composed mostly of polyvinyl chloride, or PVC, that is used to enclose electrical wiring. Because it is more flexible and easier to install, plastic conduit offers an attractive alternative to its metal counterpart in certain construction situations. But concern over the risk of smoke toxicity prompted the National Fire Protection Association to take action. The 1984 National Electric Code—a model code published every three years by the association, which local jurisdictions can choose to adopt—recommends that PVC conduits be permitted only in structures no taller than three stories. Some cities have already taken other steps. For example, New York City spent $2 million in 1982 to replace with metal some of the PVC conduits in the subway system.

Other regulations related to smoke toxicity include general proscriptions in several states and local jurisdictions to the effect that building materials cannot release combustion products more toxic than those of wood. But these laws, written years before scientists began developing standard laboratory tests of smoke toxicity, go largely unenforced. However, about a half-dozen states are now taking a hard look at just how toxicity testing might be used to regulate a broad spectrum of products. What New York decides to do with the ADL report could set the stage for these other states to act.

### Report Gets Mixed Reviews

The ADL study evaluated the dozen or so published methods for testing the toxicity of combustion products, including one that Birky helped develop when he was at the National Bureau of Standards (NBS). The study, led by Rosalind C. Anderson, concluded that the most useful test is one developed by Yves Alarie and Anderson when she was at the University of Pittsburgh. Anderson said she sees no conflict of interest in recommending a test that she helped design; she also helped design the NBS toxicity test that was rejected.

In the Pittsburgh test, mice in a special chamber are exposed to smoke from burning materials. This method determines what's called an $LC_{50}$—the amount of material that produces a "lethal concentration" of smoke noxious enough to kill 50 percent of the animals exposed for 30 minutes. (Anderson says a shorter period wouldn't address most fire situations where people are waiting to be rescued,

U.S. fire deaths are declining (graph, opposite page). Plastics-industry officials say this means synthetics can't be making fires more dangerous. But others claim that improved firefighting methods and greater use of sprinklers and smoke detectors have masked the increased hazard posed by synthetics. They also cite firefighter reports that today's fires burn hotter and smoke develops faster and is more irritating.

In the Westchase Hilton fire (opposite, right), researchers found that the victims were exposed to toxic hydrogen chloride and hydrogen cyanide given off by synthetic room furnishings. Building materials, such as plastic pipes (opposite, lower left), can also generate deadly gases.

and a longer period would probably kill all the mice.) The lower the $LC_{50}$ value, the more toxic the material. According to the Pittsburgh test, the $LC_{50}$ of Douglas fir, for example, is 31 grams, while that of wire coated with polytetrafluoroethylene (Teflon) is 3 grams.

The ADL report recommends that manufacturers submit $LC_{50}$ data on their products to a state agency, where the information would be accessible to architects, engineers, and the public. Anderson says the ADL study ruled out, for the time being, other regulatory uses of the data, such as bans on specific materials and requirements for product labeling.

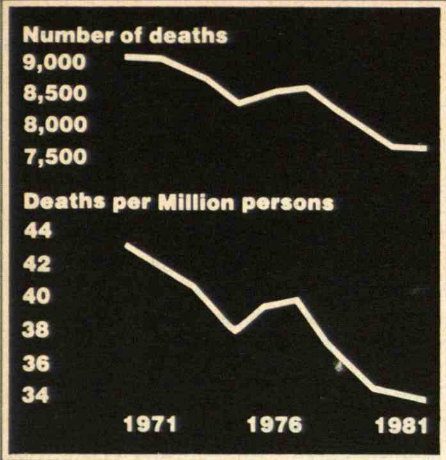
Reviews of the report have been mixed. Firefighters and fire-safety officials have generally approved, though some say they would have preferred ADL to voice stronger recommendations, such as the use of $LC_{50}$ data to ban specific products. Critics, on the other hand, have charged that a smoke-toxicity data bank would be worthless. "The problem here is that the kind of data collected will be of no value in saving lives," said G.R. Munger, president of the Society of the Plastics Industry, in his comments to the New York Legislature. Simple, small-scale toxicity tests are not representative of the complex hazards of real fires, he said.

In fact, Munger and others claim that such tests could sometimes lead builders to select products that ignite more easily or whose flames spread faster as a tradeoff against their lower combustion toxicity. For example, PVC has largely replaced cotton as an insulating material for electrical wires, in part because its higher ignition temperature makes it less likely to burn. "We think that's an example of increased fire safety from using plastics," says SPI's Lawrence. He also points out that many fires are caused by electrical short circuits, which often result from improperly grounded metal conduits. And while burning PVC plumbing has been implicated—controversially—in some of the 83 deaths in the MGM Grand fire, he points out that a short in a metal conduit started the fire. Thus, even if tests show gross differences in smoke toxicity, the results should be interpreted with caution since other flammability properties are involved in assessing hazard.

Barbara C. Levin of the NBS Center for Fire Research agrees that an $LC_{50}$ data bank is unnecessary. In her comments to the New York State Legislature, she stated that "a toxicity test alone does not constitute toxic hazard assessment." She noted that NBS is now developing a computerized method for assesing the hazards of combustion that takes into account a product's rate of heat release, ignitability, and other fire-related characteristics as well as smoke toxicity. The method is expected to be ready in about five years.

ADL's Anderson counters that, while more research will undoubtedly improve assessment techniques, the fact that most fire victims are being killed by smoke means we shouldn't sit idly by until a hazard index is developed. And there is another pressing issue. "As melodramatic as it sounds, firefighters are out there watching their colleagues being hurt and even die," she says. She cites a study by the National Fire Protection Association that found that firefighters say that fires are getting harder to fight. Fires burn faster and hotter, and smoke develops more rapidly and is thicker and more irritating to the respiratory tract. "There appears to be an increase in firefighter casualties from smoke inhalation," the association concluded. "The smoke in today's fires . . . may be producing increased risk of inhalation injury to firefighters as well as to building occupants."

SPI officials maintain that there is only anecdotal evidence to support the contention that fires are now more threatening because of smoke from burning plastics. They point to two SPI-supported studies—one reported in March 1979 by the Harvard School of Public Health and the other in May 1981 by the Southwest Research Institute—that show high levels of carbon monoxide to be the most hazardous air contaminant detected by gas-sampling




equipment worn by firefighters.

However, Birky says the SPI-supported studies are not only limited; they also do not explain why postfire investigations have turned up sublethal doses of carbon monoxide in victims' blood. Such doses were found not only in the Westchase fire, he says, but also in the MGM Grand disaster, where half of the 83 people who died at the scene were found to have sublethal carbon-monoxide levels. He acknowledges that such an effect has been uncovered in only a few instances, "not because it doesn't occur, but because the follow-up toxicological studies on the victims have not been thorough enough to demonstrate this factor." (Birky has left the Foundation for Fire Safety, located in Rosslyn, Va., to start a fire-toxicology consulting service in Boonsboro, Md.)

**Charges and Countercharges**

Calling this the most important question in fire safety, the foundation last year embarked on a national study to pinpoint which toxic gases are causing deaths by smoke inhalation. "We have developed a post-mortem protocol," says Thomas Casey, former executive director and now a consultant to the foundation, "and we are working with paramedics, medical examiners, and fire services to ensure that more complete autopsies are performed on fire victims. For example, we specify that blood samples be drawn within three hours of the fire and that they be properly stored and handled." Thirteen cities, including Seattle, Miami, Denver, and Dallas, are already participating in the study. Thus far, the foundation has collected data on 60 fire victims, but plans to gather data on 250 before drawing conclusions.

SPI officials are already skeptical of the study. They point out that the foundation is largely funded by the Allied Tube & Conduit Corp. and other members of the metal industry. These firms, according to an SPI statement, have "embarked on a 'fear and smear' campaign against plastic products in order to win back [their] position in the marketplace." John Lison, vice-president and general counsel for Allied, counters such charges: "Instead of developing safe products, the giant plastics industry has used its extensive public-relations apparatus to attempt to turn what is a very vital question of public safety . . . into a seemingly commercial battle between two industries."

"There's no doubt that this is a commercial fight," says Gordon Vickery, president of the foundation and former head of the U.S. Fire Administration. "I do not offer one ounce of apology for the funding of the foundation by the Allied Tube & Conduit Corp. We invite, as we have in the past, the plastics industry to support us in like manner."

The impact of commercial interests can also be seen in recent actions of the National Institute of Building Sciences (NIBS), created by Congress in 1974 to unify and improve the heterogeneous network of U.S. building codes. When the rash of hotel fires brought burning plastics under close scrutiny, NIBS officials felt pressured to address this issue. In June 1982, they formed a 12-member task force to consider whether the results of laboratory tests of combustion toxicity, such as the NBS and Pittsburgh methods, should be incorporated into building codes. For example, a code could forbid the use of products judged by one of those tests to be more toxic than wood, unless those products are accompanied by early-detection fire-protection systems such as smoke detectors and sprinklers. Wayne Ellis, manager of industry standards for the H.B. Fuller Co., which makes synthetic adhesives, sealants, and coatings used in building construction, was named chairman. The task force also included SPI's Munger, two DuPont officials, and representatives from Dow Chemical, Rohm & Haas, and Armstrong World Industries. Only one member—James R. Bell of the National Fire Protection Association—was not affiliated with a corporation, trade association, or the government.

Later that summer, the task force hosted

PHOTOS: UPI; HOUSTON CHRONICLE; FOUNDATION FOR FIRE SAFETY

a meeting and invited people holding points of view at odds with those of the synthetics industry, but the group did not include these people on the agenda of speakers. "The only speaker designated to explain the 'state-of-the-art' in toxicity testing methodology," says an Allied spokesperson, "was Gordon Hartzell of the Southwest Research Institute. Significantly, the SRI study that formed the basis of Hartzell's remarks and conclusions was commissioned and paid for by none other than the Society of the Plastics Industry." Thus, it came as no surprise, says the Allied representative, that Hartzell described available tests as "primitive" and insufficiently developed for regular use.

Ultimately, in an official report released last May, NIBS recommended against setting building codes based on smoke toxicity. Part of its reasoning was that such codes would not include interior furnishings. But Anderson counters that while it is tempting to think of furnishings as the more significant hazard, "fires do start in the basement, attic, or storage area and travel between the walls, burning only structural elements." She also says the distinction between structural and furnishing fires "has never been addressed on a percentage basis; nobody has measured it."

More importantly, however, the NIBS report concluded that laboratory tests of combustion products are inadequate and should not yet be used to compare the smoke toxicities of any materials. But this is "ridiculous," says Eugene Rider of the United States Testing Co., in Hoboken, N.J.. "Take the NBS protocol: years of research and millions of dollars went into it," he says, adding that the quality of research behind that test exceeds that upon which most flammability tests are based.

### Money—and Lawsuits—May Talk

Still, a group of state legislators is concerned with the cost of *not* taking action. This group, called the National Task Force on Firegas Toxicity, is composed of lawmakers from California, Illinois, Indiana, Ohio, Maryland, and Michigan. While the group believes the benefit of regulating smoke toxicity could ultimately be measured in lives saved, it recently focused on a "cost of not regulating" that is infinitely easier to gauge: lawsuits. Injuries and deaths from smoke inhalation are posing "a whole new series of product-liability questions," says Ohio Sen. Charles Butts. "This seems to be happening with the law-

suits stemming from the MGM fire; plastics companies have been brought into the lawsuits and may bear a liability even though they weren't responsible for how the fire started."

The task force, which has conducted several hearings on the smoke-toxicity issue, will issue a final report this year that "may very well have recommendations for legislation," Butts says. Like the ADL report to New York State, this one will probably call for establishing a data-gathering agency for combusion toxicity. "We need to have some kind of data bank; we need to use some kind of testing mechanism," Butts says. "Now, 'specifiers' [architects, engineers, buildings owners, and so on] have no information on which to base their decisions. They are making decisions that may be allowing buildings to become more dangerous, and that may be leaving themselves vulnerable to lawsuits." Butts also says that insurance companies, fearing "their clients will find themselves in a toxicity lawsuit," may soon become involved in the smoke-toxicity debate. This, he envisions, would provide a powerful impetus to the movement to establish procedures for testing the combustion toxicity of building and furnishing materials.

That's the best-case scenario, ADL's Anderson says. For a worst-case scenario, she draws parallels to the asbestos story. Information on the health effects of asbestos "had been there for years," she says. "Unfortunately, some of the people who were in positions to make decisions and change policy had only fragments of that information. That's the type of situation some people are saying is developing as we bring new products into buildings. There is the fear that we are stacking the indoor environment with materials that, if we could only see all the combustion-toxicity data available, would be deemed unacceptable in terms of fire safety."

Says Anderson: "I'm not suggesting we ban products—we don't have enough data yet to take this regulatory route. And product labeling is good for only about 30 seconds; once you have the wallpaper up, you've forgotten what's on the label. But if we had a centrally located combustion-toxicity data bank, we could start drawing useful conclusions."

*LINDA GARMON is chemistry editor of* Science News. *She is now a fellow in the Vannevar Bush Fellowships in the Public Understanding of Technology and Science at M.I.T.*

# SPECIAL SUMME PRO

**BEGINNING MON., JUNE 4**
- Individual Judgment.
  Professor: Max Bazerman

**BEGINNING WED., JUNE 6**
- Effective Negotiation Techniques.
  Professor: Max Bazerman

**BEGINNING MON., JUNE 11**
- Controlling Acid Rain.
  Professor: James A. Fay
- Applied Materials Technology:
  The Science and Engineering of
  Materials Processing.
  Professor: H. Kent Bowen
- Building Economics: Cases in
  Life Cycle Costing.
  Professor: Ranko Bon
- Biomolecular Modelling
  Professor: Gregory Petsko
- High-Speed Photography and
  Videography.
  Professor: Charles E. Miller
- Bargaining and Negotiation.
  Professor: Lawrence E. Susskind
- Corporate and Economic Policy
  Design with Microcomputers:
  A System Dynamics Approach.
  Professor: David P. Kreutzer
- Corporate Planning and
  Control Systems.
  Professor: Morris McInnes
- Management of Research,
  Development, and Technology-
  Based Innovation.
  Professor: Edward B. Roberts
- Orientation for Executives
  Assigned Overseas in France or
  French-speaking Countries.
  Professor: Jacqueline-H. Hill

**BEGINNING MON., JUNE 18**
- Human Factors and Computer
  Aids in Nuclear Power and
  Industrial Process Control.
  Professor: Thomas B. Sheridan
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  Microscopy of Materials.
  Professor: Linn W. Hobbs
- Data Communication Networks.
  Professor: Robert G. Gallager
- Office Information System
  Software.
  Professor: Irene Greif
- Electric Futures: Planning and
  Operation for 2000.
  Professor: Fred C. Schweppe
- Mediating Technical and
  Scientific Disputes.
  Professor: Lawrence E. Susskind
- Individual Choice and Discrete
  Data: Theory and Applications
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  Market Shares.
  Professor: Moshe E. Ben-Akiva
- Strategic Planning Systems.
  Professor: Arnoldo C. Hax
- Communicating Technical
  Information (Twenty-Eighth
  Edition: Writing and Editing).
  Professor: James Paradis
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  Processing.
  Professor: Barry L. Vercoe
- Decision Support Systems and
  the Management of End User
  Computing.
  Professor: Michael E. Treacy
- The New Production Planning.
  Professor: Harlan C. Meal
- Economics and Politics in
  Southern Africa, Political
  Risk Assessment.
  Professor: Robert I. Rotberg
- Probabilistic Risk Assessment:
  Applications and Uses for
  Decision-Making in the
  Nuclear Industry.
  Professor: Carolyn D. Heising
- Employer Options for Working
  Parents that Meet the Needs of
  Both Management and the
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  Experiments.
  Professor: Harold Freeman
- Modern Concepts in Financial
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  Professor: Stewart C. Myers
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  Professor: Robert V. Kenyon
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  Professor: Shaoul Ezekiel
- Nuclear Power Reactor Safety:
  Part 1–Thermal Power Reactors.
  Professor: Norman C. Rasmussen

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- Fields, Forces and Flows:
  Electrically Mediated
  Transduction in Biological
  Tissues, and Membrane
  Transport and Separations.
  Professor: Alan J. Grodzinsky
- Rheological Behavior of
  Polymeric Fluids with Laboratory
  Workshop.
  Professor: Robert C. Armstrong

**BEGINNING MON., JULY 2**
- Workshop in Computer Music
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  Professor: Barry L. Vercoe

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- Modern Methods for Nonlinear
  Control System Design.
  Professor: J. Karl Hedrick
- Tribology.
  Professor: Ernest Rabinowicz
- Engineering of Semiconductor
  Materials for Advanced
  Applications: GaAs in the Wake
  of Silicon.
  Professor: Harry C. Gatos
- Materials Systems Analysis.
  Professor: Joel P. Clark
- Specification and Design
  of Software.
  Professor: Barbara Liskov
- Plasma Processing for
  Microelectronic Fabrication:
  Plasma Deposition, Etching,
  and Sputtering of Thin Films
  for VLSI.
  Professor: Herbert H. Sawin

# R
# GRAMS

**BEGINNING MON., JULY 16**

- Corrosion: The Environmental Degradation of Materials. Professor: Ronald M. Latanision
- Structure and Interpretation of Computer Programs. Professor: William M. Siebert
- New Developments in Modeling, Simulation, and Optimization of Chemical Processes. Professor: Lawrence B. Evans
- Finance for International Managers. Professor: Donald R. Lessard
- Controlled Release Technology: Polymeric Delivery Systems for Drugs, Pesticides and Foods. Professor: Robert S. Lanager
- Nuclear Power Reactor Safety: Part 2–General Safety Issues. Professor: Norman C. Rasmussen

**BEGINNING MON., JULY 23**

- Synthesis of Chemical Process Flowsheets: Grass-Roots Design and Revamps. Professor: George Stephanopoulos
- Operations Management in the Services Industries. Professor: Richard C. Larson
- The Dynamics of Health Service Systems: Strategic Planning for Complex Health Organizations. Professor: Edward B. Roberts

**BEGINNING MON., JULY 30**

- Optical Propagation, Detection, and Communication. Professor: Jeffrey H. Shapiro
- Data Flow Concepts in Computer Language and Architecture. Professor: Arvind
- Robot Manipulators, Computer Vision, and Automated Assembly. Professor: Berthold K.P. Horn
- Management of Medical Technology: Development, Utilization and Cost. Professor: Stan N. Finkelstein

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- Analytic Methods for Infrastructure Maintenance and Rehabilitation. Professor: David H. Marks
- Lasers, Microwaves, Ultraviolet, Magnetic Fields, and Ultrasound: Biophysical and Biological Basis, Applications, and Hazards in Medicine and Industry. Professor: Padmakar P. Lele
- Control of Transport Phenomena During Crystal Growth of Semiconductor Materials. Professor: Julian Szekely
- Chemically Modified Surfaces: Preparation, Characterization, and Applications. Professor: Mark S. Wrighton
- Theoretical Models for Microwaves Remote Sensing with Radiometers and Radars. Professor: Jin-Au Kong
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- Computer Aided Techniques in Food Technology. Professor: Marcus Karel
- Principles of Toxicology. Professor: Steven R. Tannenbaum
- Industrial Rheology: Principles and Practice. Professor: Chokyun Rha
- Marine Transportation Management. Professor: Henry S. Marcus
- Public Transportation Service and Operations Planning. Professor: Nigel H.M. Wilson
- Logistics Analysis for Carriers and Shippers. Professor: Yosef Sheffi

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- Fermentation Technology. Professor: Daniel I.C. Wang
- Decision Analysis: Basic Concepts and Applications. Professor: Alvin W. Drake
- Port Management and Planning. Professor: Henry S. Marcus
- Microcomputer Applications in Transportation. Professor: George A. Kocur

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- Fluidized Bed Coal Combustion. Professor: Adel F. Sarofim
- Recent Advances in Welding Technology. Professor: Koichi Masubuchi
- New Approaches to Ancient Cosmology: Stonehenge to Plato. Professor: Harald A.T. Reiche
- Resource Management: A New Approach to Corporate Planning. Professor: Jeremy F. Shapiro
- Multiple Objective Decision Analysis for Individuals and Groups. Professor: Alvin W. Drake

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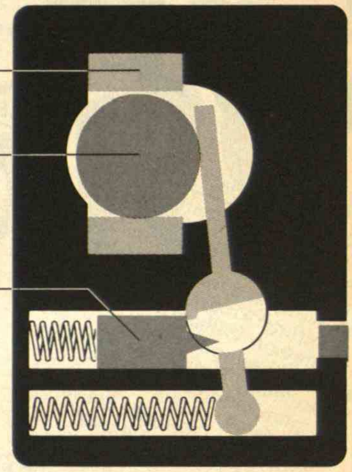
# New Airbags: Low Tech, Low Price

The airbag, designed to protect passengers in car crashes, has so far resulted mainly in heated disputes. Consumer groups and insurance companies favor it, but the airbag costs at least several hundred dollars because of its complexity. Some consumers balk at paying that much, and the automobile industry doesn't want to increase sticker prices. The National Highway Traffic Safety Administration (NHTSA) has been preoccupied for over a decade trying to decide whether to require automakers to install the safety device on all new cars. This dilemma may be coming to an end: a simple, cheap airbag may soon be available that will satisfy all parties.

Designing any airbag is not easy. "First, you need to pick up a signal at the onset of a crash to predict how violent it will be, so you know whether to deploy the airbag," explains Michael Finkelstein, associate administrator for research and development at NHTSA. "Second, you need to deploy the airbag quickly enough to protect the passenger." A crash into an immovable barrier such as a tree is effectively over in 80 to 120 milliseconds—one-third of an eyeblink. So to do any good, the bag must inflate in 40 or 50 milliseconds, according to John Morris, physical scientist in NHTSA's Occupant Restraint Group. That's not much time.

Because the front of a car is designed to collapse like an accordion, delaying and diminishing the impact on the rest of the vehicle, airbag designers have put sensors where the force of the crash is strongest—one near each headlight. The sensor is typically a piece of ferrous metal restrained from closing an electrical circuit by a magnet. If the deceleration force reaches 10 times that of gravity, the sensor breaks loose from the magnet and closes the electrical circuit. This in turn sets off an explosive that produces gas to inflate the airbag. Hitting a solid barrier at about 10 miles an hour does it, according to Morris.

The trouble is that such a system is expensive. In addition to the basic system, a diagnostic module with a monitor light in the dash is necessary to test the circuitry. Most systems add a capacitor to hold enough electricity to fire the trigger in case battery power is lost, and some add a backup sensor in the dashboard so underhood tinkerers can't accidentally fire the bags. If millions of these were installed, manufacturers estimate each system would cost \$300; for smaller volumes the price could climb toward \$1,000.




**This mechanism to sense a car crash and inflate an airbag may look like a Rube Goldberg contraption, but it is much simpler than the electrical systems of previous designs. When the deceleration force is four times that of gravity, the sensing ball pushes the spring-loaded lever far enough forward to release the firing pin. The pin strikes a cap, detonates an explosive, and inflates the bag.**

However, by simplifying the design, the Breed Corp., of Lincoln Park, N.J., whose primary business is making fusing mechanisms for rockets and artillery shells, may have changed the picture. Convinced through computer analyses of test data that crashes could be reliably sensed within the passsenger compartment, Breed developed a mechanical sensor designed to be attached to the airbag and trigger it directly. Since the impact of the crash is dampened in the passenger compartment, the sensor responds when the deceleration force is only four times that of gravity. A metal ball in the sensor is moved forward by inertia against a spring-loaded arm and releases a firing pin. This pin hits a percussion cap and thereby triggers the explosive bag inflator. The system needs no sensors in the front of the car,

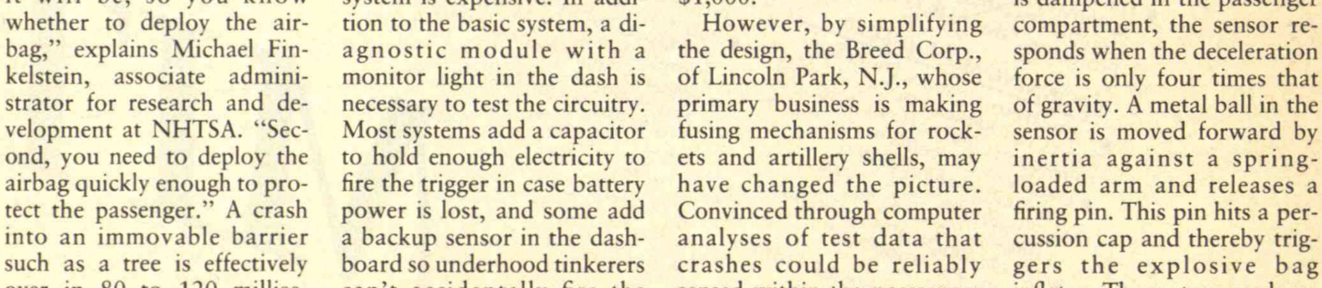





DIAGRAM: OMNIGRAPHICS

and thus no electrical system, electronic monitoring device, or capacitor.

"The whole—airbag, inflator, and sensor—is one unit," says Ted Thuen, executive vice-president of Breed. "It takes only four screws to install." Breed says that the driver's-side unit, mounted on the steering wheel, could be mass-produced for $50, the larger passenger-side unit for $75.

Breed has tested its system in car crashes against barriers and says it works. NHTSA is planning to buy airbags equipped with Breed's sensors for tests, and may also install them in a fleet of 500 police cars. "We don't know yet that the Breed system will work," says Finklestein. "But it's really worth a look."

If it does work, the new technology may solve the public-policy problems long associated with airbags. Previously, the only way to make them economically feasible was to mandate that all cars be built with them. Breed's single-unit system appears to be so cheap that car buyers could order it as an option or buy it from—in Finkelstein's words—"Midas airbag shops." Breed has suggested that NHTSA simply require auto manufacturers to produce steering wheels and dashboards capable of accepting the airbag units.

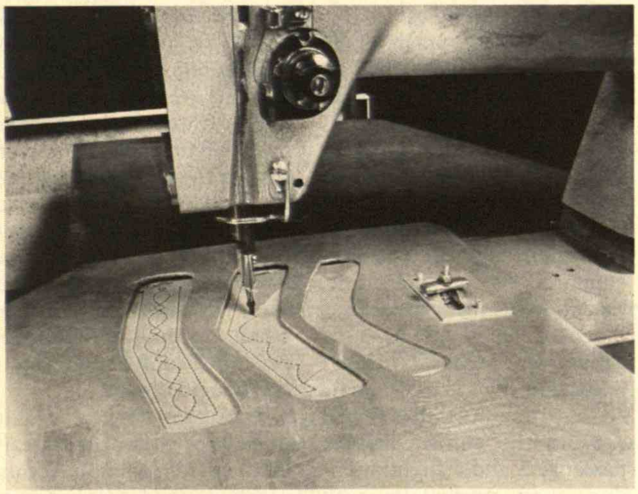
After trying unsuccessfully to revoke the portion of Federal Motor Vehicle Safety Standard 208 that mandates some form of passive restraints in automobiles, the Reagan administration is once again reviewing the regulation. It has requested public comment on a requirement similar to the one Breed proposes. NHTSA officials say that a ruling on the issue could be made as early as April.—*David Kennedy* □

# Can Computerization Save U.S. Shoemakers?

Since its peak in 1968, the U.S. shoe-manufacturing industry has lost 97,000 production jobs. Most of these went to cheaper foreign labor markets—initially in Spain and Latin America and later in Korea and the Philippines. Americans are now buying more shoes made abroad than at home.

Despite the dark statistics for "sunset" industries such as shoemaking, some economists are optimistic that computers can provide a new dawn. Especially in the more labor-intensive steps of shoe manufacturing such as cutting and sewing, computers can reduce production time to nearly a fifth of that required with hand labor, and hence reduce costs. The rows of fancy stitches that distinguish Western boots, and the complicated embroidery around a running shoe's emblem—the Nike "swoosh" or the New Balance "N"—would be prohibitively expensive to sew by hand with costly U.S. labor. But a computerized stitching machine can cut costs enough to keep some shoe-production jobs in the United States.

The first computerized sewing machine was introduced in the early 1970s by United Shoe Machinery of Beverly, Mass. The stitcher's minicomputer (a fairly substantial machine despite the name) required massive doses of power and a temperature-controlled environment. However, a two-headed sewing machine developed recently by Data Technology of Woburn, Mass., employs a microprocessor that uses a lot less power and does not require air-conditioning. The machine can sew up to 2,200 stitches per minute. All workers have to do is load the material for the shoe "uppers," control the stitching speed, and start the machine going again if the thread breaks.



**Computerized stitchers, such as this one made by Data Technology of Woburn, Mass., might save the U.S. shoe industry. But shoemakers will use the stitchers mainly to produce specialized lines such as cowboy boots, and industry employment will never rise to former levels.**

Texas Boot installed this two-headed stitcher at its plant in Lebanon, Tenn., and plant manager Robert Reed liked the way it worked so well that he recently ordered two more machines. The computer excels at intricate work, such as sewing the six rows of stitches with colored threads on El Dorado boots. Even when the machine is running at full speed, stitching a pair of Eldorados takes half an hour. In this case, the computerized stitcher's attraction is more in its artistry than its frugality—Eldorados retail in specialty shops for $350 and up.

Donald Skendarian, vice-president of Data Technology, thinks high-tech equipment such as his computerized stitcher can increase productivity enough to make American shoes competitive with foreign imports. Nike's figures indicate that sewing the eyestays on 12 pairs of its "Equator" running shoes takes 55 minutes by hand and only 8 minutes with the aid of its own computerized stitcher.

### "Deskilling" Jobs

But other observers aren't so optimistic about the benefits computers will confer on this "mature" industry. The late William Abernathy, Harvard Business School professor and author of *Industrial Renaissance*, said that computers can only help prevent further erosion in specialty markets such as running shoes. Even Peter Stipe of Nike, which happily employs

computerized sewing machines at its plant in Sacco, Maine, is skeptical. "Computerized stitching will speed up the rate and will certainly enhance quality," he says. "But so far it hasn't evened up the difference in the overall cost of producing shoes." Production workers in the shoe industry earn $1 an hour in underdeveloped countries but $5 an hour here, according to the U.S. Department of Commerce.

Since computerized stitching machines are relatively simple to run, training operators takes about half as long as training traditional stitchers. Of course, shoe companies also pay machine operators less than skilled stitchers. Thus, part of the way shoe manufacturers are able to cut costs with computers is through "deskilling" the operation—hardly a benefit for workers.

In addition, fully computerized operations will not employ as many people as the old factories did. "My guess is that shoemakers with computerized machinery will probably employ a third fewer workers," said Abernathy.

New technologies may allow some U.S. shoemakers to stay competitive, but even proponents of computerization do not claim that it will bring back the golden era. More than 50 U.S. shoe factories have closed just in the last two years. Even Nike recently laid off 350 workers at its Exeter, N.H., plant in favor of cheaper labor in Maine. Bass Shoes announced it would be halting production at its plant in North Jay, Maine, putting 250 people out of work. And losses in some kinds of shoe manufacturing will never be recouped. For example, children's shoes might as well be made cheaply overseas: they are outgrown too quickly for companies to bother making them to last.—*Renée Loth* ☐

# When an Airplane Crashes

Airplanes generally crash headfirst, so when Dr. Richard G. Snyder of the University of Michigan's Transportation Institute flies on a commercial airliner, he usually requests a seat in the rear. In a Boeing 727 or any other plane with a rear engine, though, he opts for a seat in the middle, near an over-the-wing exit. His view of the safest seats is disputed by Dr. Edmund J. Cantilli of the Institute for Safety in Transportation, who warns that a seat over the wing of a Boeing 727 rests on top of thousands of gallons of volatile jet fuel. And Brad Dunbar of the National Transportation Safety Board (NTSB), the federal agency that reports on major U.S. air crashes, disputes both claims. "The accidents that are survivable show fatalities everywhere," he says.

Safety experts may not agree on the best seat in the event of a crash, but almost all concur on one point: the seats themselves are unsafe. In a 1981 study the NTSB concluded that in survivable crashes, poor construction of the seats accounts for most injuries and fatalities.

Consider the crash of an Allegheny Airlines DC-9 in June 1976 at Philadelphia International Airport. Passengers jackknifed over their lap belts at impact: their heads struck the plastic tray tables on the seats in front, and their legs hit the seat supports. At the same time, the floor buckled upward as much as 12 inches in some areas. The seats couldn't withstand the forces; 95 seats tore loose and bounced around the cabin. Twelve passengers and a flight attendant were pinned beneath them. Thirty-six people were severely injured, most with spinal fractures.

These passengers were lucky. There was no fire, as there is in about half of all survivable crashes. In December 1972 a United Airlines Boeing 737 crashed in a suburban area near Midway Airport, Chicago. Seats from the left side of the plane were thrown out of their track, blocking aisles and exits. Meanwhile, a fire that had started outside the plane burned through the fuselage. The polyurethane seats were among the first items to blaze up inside the aircraft. When heated, these revert to a petrochemical fluid almost as flammable as jet fuel, and also produce toxic fumes when burning. Forty-three persons died, twenty-seven of fire-related causes.

Those seats, like the seats in all U.S. passenger aircraft, met Federal Aviation Administration standards, but these standards were issued some 30 years ago. At the FAA, says Synder, the emphasis is on preventing a crash: "Very little attention is given to protecting the individual when a crash happens."

Snyder and other safety experts recommend a number of measures to improve seat safety. One is turning the seats around so that they face the rear. In a rear-facing seat, most of the crash impact is delivered to the back of the seat, not to the occupant and the lap belt. The lap belts themselves should be strengthened—present ones are much weaker than those used in automobiles—and they should be supplemented with shoulder harnesses. Shock absorbers should be placed on seat legs to cushion the impact of a crash and spread out deceleration forces over a longer period. And the polyurethane should be replaced by fire-resistant fiber blends.

The technology required to implement these changes has been around for years. Corporate jets as well as many U.S. military aircraft include these features and more. And there are signs that the FAA is at last coming around to the view that the commercial airline passenger deserves a safe seat, too. After the recent fire during an Air Canada crash in which 23 people died, the FAA proposed that all airline seats be wrapped in a fire-blocking layer developed by the FAA's Technical Center. This summer the Technical Center will crash-test a full-size airliner filled with experimental seats and other safety features to see how they fare.

But given the glacial speed of the FAA's regulatory process, airline seats may not get much safer before the year 2,000. About all you can do until then is ask for a seat near an exit. Or become a corporation president.—*Barbara Ford* ☐

# Gene-Spliced Organisms in the Environment

Contained mainly in laboratories until now, genetically engineered plants and bacteria may be released into the environment as soon as this April. These genetically modified organisms promise substantial benefits for agriculture, waste treatment, and basic research. However, some environmentalists and scientists believe the release of new microbes and plants should be regulated to ensure that nothing goes awry.

Public concern was first raised last fall, when the federal Recombinant DNA Advisory Committee (RAC) of the National Institutes of Health approved an experiment by two plant pathologists at the University of California at Berkeley. The scientists, Steven Lindow and Nickolas Panopoulos, proposed to spray potato fields with a genetically engineered strain of *Pseudomonas syringae*, a bacterium commonly found on plant leaves, to reduce frost damage.

The natural strain of the bacterium produces a protein on its surface that serves as a nucleus, or seed, for water to crystalize on and freeze. Without such a nucleus, dew, which is very pure water, can be "supercooled" to 25° Farenheit without freezing. Plants covered with bacteria that lack the protein can survive a light frost, since the water on the leaves will not turn to ice and damage the sensitive tissues.

A group of environmentalists led by Jeremy Rifkin, head of the Foundation on Economic Trends in Washington and an opponent of all genetic engineering, successfully sued to delay the research. The group claimed that the environmental effects required more study. Rifkin suggested that the bacteria might get into clouds and prevent normal condensation of moisture, a highly disputed scenario. Lindow and Panopoulos believe they will soon resolve these issues so they can perform the experiment this spring. Still, the controversy illustrates the dilemmas, both scientific and political, in weighing the risks of releasing genetically engineered bugs into the environment.

Lindow and Panopoulos consider their experiment very safe. Chemically mutated bacteria have already been legally and safely sprayed on fields to reduce frost damage. These bacteria were derived from natural bacteria that had been exposed to chemicals to mutate genes at random. The resulting strains that turned out to produce relatively little frost damage were selected for use. Lindow and Panopoulos argue that their recombinant bacteria were even safer than the chemically altered ones: while the recombinant technology simply deleted the ice-nucleation gene, the chemical mutagens might have altered other genes in unpredictable ways. So why the fuss over recombinant bacteria?

Some scientists think this argument skirts the general question about the safety of releasing genetically engineered organisms. David Pimentel, a prominent entomologist at Cornell University, supported Rifkin's lawsuit. He believes that the ecology of recombinant organisms should be better understood before they are let loose. "Half of all agricultural pests in the United States have been introduced from other habitats," he notes.

Before a genetically engineered organism is released, Pimentel recommends answering these questions:

☐ Could it cause diseases in plants or amimals?

☐ How might it affect "non-target" organisms? If an engineered organism is intended to reduce the harm done by a particular insect to a plant, how might the organism affect other plants and insects?

☐ Can the organism pass any of its genes to related species?

☐ What will be the fate of the organism? Might it proliferate, spread to other habitats, and survive there?

☐ If something goes wrong, can the organism be contained by some biological or chemical means?

In the case of the Berkeley experiment, Pimentel agrees that "the risk is small." This is primarily because genetic engineering was used to *remove* a gene. What worries Pimentel is *adding* new genes to a natural microbe. When put into a foreign organism, a gene may not function at all—or it may function in unexpected ways. A bacterium equipped with a gene from a different bacterial species might produce a protein that could prove harmful, especially if the recombinant microbe finds its way into new areas of the environment.

This question of unforeseeable consequences will continue to haunt the debate about releasing genetically engineered organisms. This question also must be answered in government regulations weighing the benefits against the possible risks of using recombinant organisms in the environment.—*Christopher D. Earl* ☐

# The EPA Looks at Gene-Splicing

So far, the National Institutes of Health have exercised control over recombinant-DNA research through their Recombinant DNA Advisory Committee (RAC). But now that genetically engineered organisms are to be released into the environment, the Environmental Protection Agency (EPA) is planning to play a regulatory role and hopes to publish preliminary guidelines soon.

The agency claims authority in this area under two statutes. First, the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) requires the EPA to regulate not only chemical pesticides but also living organisms used to control pests. These organisms may be natural predators, such as *Bacillus thuringensis*, a parasite used to control the Japanese beetle, or genetically engineered microbes. The experiment proposed by researchers at the University of California at Berkeley, in which genetically engineered bacteria will be used to reduce frost damage to potato leaves, could be regulated under FIFRA, according to Fred Betz of the EPA'S Office of Pesticide Programs (OPP). The reason is that the modified bacteria will outcompete the natural bacteria—in effect, the pests—that aggravate frost damage.

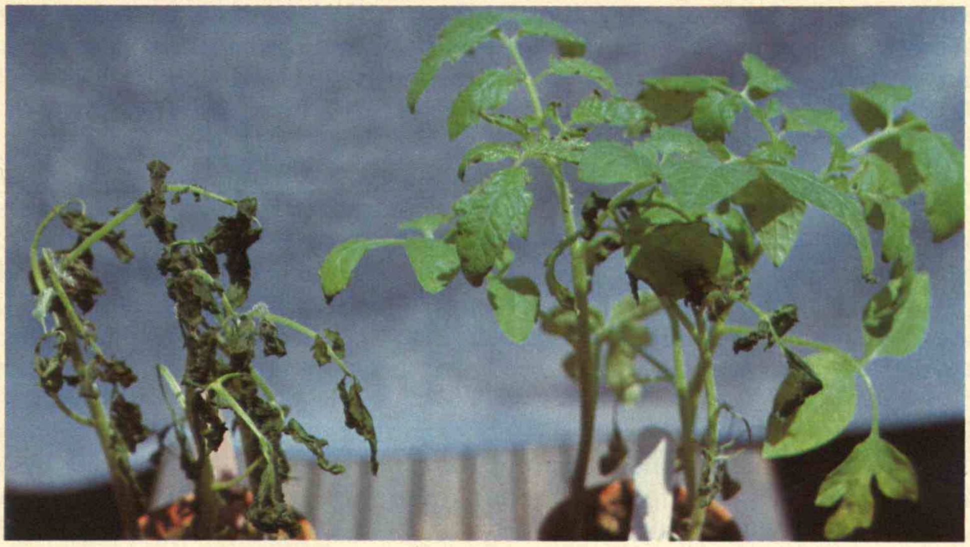
The OPP is considering

more stringent requirements for genetically engineered pest-control agents than for natural agents. At a minimum, the OPP will require manufacturers to describe how they created an organism and the extent to which it differs from its parent organism. The OPP may require researchers to get permission even for small-scale field-testing of genetically modified agents. (This is not required for chemical pesticides, as they will not proliferate.)

Under the Toxic Substances Control Act (TOSCA), the EPA also claims authority over genetically engineered organisms for nonpesticide uses such as cleaning up oil spills. TOSCA requires manufacturers to notify the EPA before commercially producing any "new chemical substance." Some people question whether a new gene inserted in a microbe truly constitutes a "new chemical substance." However, Ann Hollander, project manager for biotechnology in the EPA's Office of Toxic Substances, says that Congress intended TOSCA to fill gaps left by other environmental laws, and to cover products that might otherwise be neglected. Thus, EPA lawyers claim that new DNA molecules can be considered chemical substances under TOSCA. And since the DNA molecules are not active by themselves, risk analysis will have to be carried out while they are in their biologically meaningful state—in organisms. Of course, the biotechnology industry may well dispute this reasoning; Hollander admits that a lawsuit is entirely possible.

If courts uphold the EPA, the agency will require notification on all recombinant organisms to be manufactured for use in the environment. But under TOSCA the manufacturer will not have to prove that the recombinant organism is safe. Instead, if the EPA wants to prevent its release, the agency will have to show that it poses unacceptable risks. And TOSCA does not cover field-testing.

Some people in the biotechnology industry are skeptical about the EPA's ability to regulate recombinant organisms, since the agency has few experts in molecular biology. The agency says it is hiring such experts and is working with the Agriculture Department, the RAC, and the Food and Drug Administration. And despite their fear of "overregulation," many in the biotechnology industry cautiously favor the EPA approach. The alternative, they fear, is a proliferation of lawsuits or further legislation.—*Christopher D. Earl* □



**Even if the temperature drops to −5° C, pure dew may become "supercooled" and not freeze. However, the common bacterium *P. Syringae* provides a nucleus for ice to form on, damaging leaves. Researchers have sought to inhibit these nuclei from forming.**

**(Top) Both the lefthand and center corn plants were sprayed with *P. Syringae*. However, the center plant had been treated with "antagonistic" bacteria that do not form ice-crystalization nuclei, and that outcompete the *P. Syringae*. As a control, the righthand plant received no *P. Syringae*.**

**(Bottom) A similar experiment was carried out on tomato plants, but a chemical was used to inhibit *P. Syringae* from forming ice-crystalization nuclei.**

**Researchers have recently used recombinant-DNA techniques to alter *P. Syringae* itself, so that it does not form ice-crystalization nuclei.**

PHOTOS: STEVEN LINDOW

# SCIENCE/SCOPE

<u>In a step toward faster and more powerful integrated circuits</u>, a Hughes Aircraft Company research team has made submicrometer transistors using focused ion beam lithography. The group made N-channel silicon MOSFETs with self-aligned submicrometer polysilicon gates. The smallest dimension of the gates ranged from 0.35 to 1.2 micrometers. The focused ion beam was used to expose a highly sensitive resist, which provided a mask for reactive ion etching the polysilicon by a combination of chlorine and fluorine-based etch gases. Outstanding electrical performance was obtained for the N-channel FETs, which employed a 100-angstrom-thick gate oxide.

<u>F-15 Eagle pilots use the latest computer technology</u> to manage advanced systems in their skyborne offices. Improvements give the F-15's unique "look-down shoot-down" radar 10 times the memory of a 48K personal computer. The F-15's central computer and armament control system will be enhanced by increasing storage and reducing pilot workload. Under the multistaged improvement program (MSIP), the radar's memory eventually will increase to 1 million words and its processing speed will triple to 1.4 million operations per second. The resulting radar will have fewer parts and increased reliability. Hughes builds the F-15's AN/APG-63 radar under contract to McDonnell Douglas for the U.S. Air Force.

<u>An optical fiber that survives baking, stretching, and radiation</u> promises to find many important military uses. The aluminum-coated fiber, developed by Hughes research scientists, was subjected to severe environmental testing. It withstood temperatures up to 400°C, high strain (2%) at temperatures to 400°C, and a heavy (1 megarad) dose of cobalt radiation. Ordinary plastic-coated fibers would have melted, snapped, and lost their ability to transmit light. The metal-coated fibers will replace electrical wiring in many avionic and seaborne systems.

<u>Six gallium arsenide field-effect transistors</u>, designed for power amplifiers in radar and communications applications, have been introduced by Hughes. The single- and dual-cell power transistor chips are mounted on internally matched chip carriers. The devices consist of 10-GHz, 13-GHz, and 15-GHz power FETs capable of output power levels up to 1.5 watts. They are matched to operate in a 50-ohm-in/50-ohm-out system for a full 2-GHz bandwidth.

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# Retrobreeding the Woolly Mammoth

Last year in the Soviet Union, Dr. Sverbighooze Nikhiphorovich Yasmilov, head of veterinary research at the University of Irkutsk, got hold of some cells—including some ova, or egg cells—from a young woolly mammoth found frozen in Siberia. Although the cytoplasm—the material forming the bulk of the cell—was unhealthy, Yasmilov was able to extract the nuclei. He implanted these into viable cytoplasm from elsewhere in the mammoth.

Yasmilov continued his investigations by sending some cells to Dr. James Creak of M.I.T. for testing. Creak heated the DNA from the mammoth ova until it dissociated into short lengths of code. After a number of false starts, he tried mixing it with a similarly prepared solution of the DNA of elephant sperm. The sections of elephant and mammoth code that matched "zipped themselves together," according to Creak, "as DNA is wont to do." This "paired DNA," representing the code common to elephants and woolly mammoths, was centrifuged off, leaving a residue of code that differed between the two species. The difference was less than 4.3 percent.

This started Creak thinking. The elephant has 56 chromosomes, and the mammoth has 58. "Now look at the donkey and the horse," Creak explained. "The donkey has 62 chromosomes and the horse has 64, yet horses and donkeys can mate to produce mules and hinnies. So is it unreasonable to suggest an elephant-mammoth hybrid?"

Creak communicated the good news at once to Yasmilov, who promptly set to work trying to fuse the nuclei from the mammoth ova, in their new cytoplasm, with sperm from an Asian elephant bull. As Creak points out, this delicate work requires highly skilled technicians. "In this profession," he observed, "people who can work with DNA and have it come out whole are traded like major-league baseball players, and they are even more valuable because the stakes are higher."

Creak expressed concern about the state of experimental science in general. "Some scientists like to proceed in small, carefully thought-out steps. They are like accountants, and might as well be," he complained. "I see science as high adventure, with enormous risks. Of course, the rewards are commensurately high if the gamble comes off."

Yasmilov attempted to artificially inseminate the mammoth ova with elephant sperm over 60 times before achieving fusion in eight samples. The resulting cell clusters were implanted in the wombs of Indian elephant cows. The timing of implantation is tricky, as the elephant cow must be in heat and proceed directly to the pregnant state after the embryo is implanted. Most of the elephant cows spontaneously miscarried, but two of the surrogate mothers carried to term, giving birth to the first known elephant-mammoth hybrids.

Scientists have classified the calves as woolly mammoths according to two criteria. First, the yellow-brown hair that covered the newborn did not fall out after birth, as it does in "modern" elephants. Second, the calves' jaw structure closely resembles that of mammoths.

Finding a scientific name for the young mammoth-elephant hybrid has been difficult. Professor Herman Hoffman of M.I.T.'s Linguistics Department suggests the word "mammontelephas" (it's singular), which he coined from the Russian *mammonth*, or mammoth, and the Greek *elephas*, or elephant. "It has—dare I say it?—almost a Byzantine ring," said Hoffman. Creak proposed the biological name *Elephas pseudotherias*, which would make the animals members of the Theria class of mammals. He added that the young mammontelephases belong to the order Proboscidea, having a long proboscis, or snout. It is not known whether the Russian scientists have classified the animals.

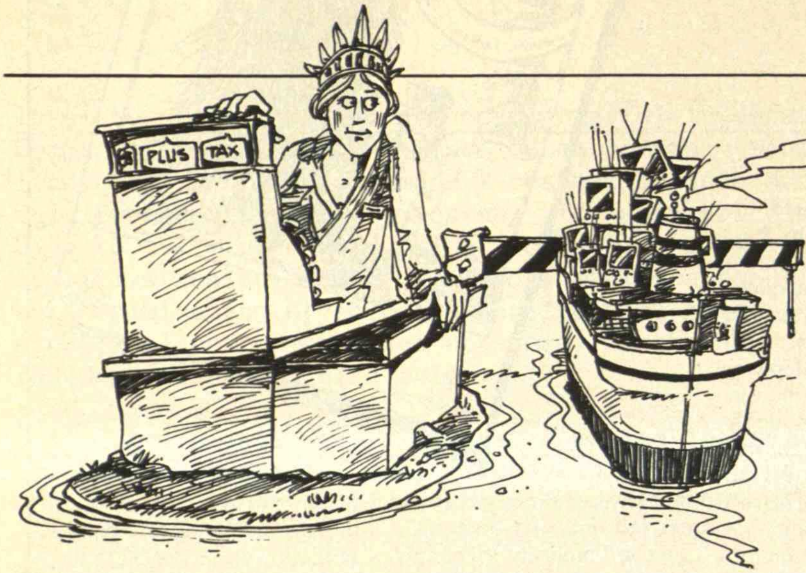
Unfortunately for those who had hoped to breed the two mammals, both are male. They are probably sterile anyway, Creak points out. Mules are almost invariably sterile because they end up with an odd number of chromosomes—31 (from the donkey parent) plus 32 (from the horse parent), making a total of 63. The 63 chromosomes in the mule's body cells divide randomly into 31 or 32 in the gametes, or germ cells. When two mules mate, the pairs of germ cells are so unevenly matched that the chromosomes simply cannot pair up. In fact, the Roman expression for "once in a blue moon" was *cum mula peperit*—"when the mule foals."

Although they will not reach adult size for another 25 years, the new mammoth calves have already exhibited extraordinary toughness by surviving the bitter cold of Irkutsk. They are being kept in an outdoor enclosure, and their reaction to the local weather conditions is being carefully monitored.

Mindful of the elephants used by Hannibal and Alexander the Great in cold climes, Yasmilov plans to train the mammontelephases to earn their keep when they reach adulthood. They could help pull immobilized convoy trucks out of the snowdrifts on the trans-Siberian highway. This is now a troublesome task, as the machinery employed to do the job may freeze in the bitter cold. The mammontelephases could also be used for logging, and there may even be a job on the trans-Siberian pipeline.

*—Diana ben-Aaron* □
*April 1, 1984*

ILLUSTRATION: JON McINTOSH




## Boosting Technology When We Import It

To build stronger innovative industries based on technology, the United States needs more funding for research—especially research on the process of turning high-tech innovations into useful goods, says Robert M. White, president of the National Academy of Engineering.

A major source of difficulty, too little appreciated, White told the M.I.T. Corporation late last year, lies in the increasing complexity of modern technology. Development costs are becoming "enormous," and sometimes the problems of implementing complex new scientific principles in devices that will work dependably in the field are overwhelming.

For an example, White turned to the article in this magazine reporting the complex technical issues involved in the search for fusion power (*see "The Trouble with Fusion" by Lawrence M. Lidsky, October, page 32*). White also cited IBM's decision last year to terminate its work on so-called "Josephson junction" computers. The company concluded that such computers, based on a high-speed semiconductor switching device that operates only at temperatures near absolute zero, simply could not be made practical for general use. "Magnificent insights continue to founder on the shoals of practicality and commercial execution," said White.

Such problems explain why George A. Keyworth II, science adviser to the White House, told the NAE annual meeting in November that he finds science advising easy but technology advising hard: "The skills needed to operate in . . . the real world are a lot different from the skills that pay off in the laboratory." It may be government policy to stimulate industry to generate and embrace new technology, but Keyworth isn't sure how to do it.

With this goal in mind, White offered an intriguing suggestion at M.I.T. (his alma mater) in December: a duty on high-technology products imported into the United States, with the proceeds supporting engineering—not scientific—research at universities. If high-technology imports come to \$46 billion (the figure for 1980), a 1 percent duty would yield \$460 million—several times the funding for engineering research now provided by the National Science Foundation.

The relationship between source and beneficiary was not accidental. The most visible symbol of the dulled edge of U.S. competitiveness is the success of foreign high technology in crossing our borders. White describes his high-technology duty as "a feedback device for prompting technological competitiveness." □

## Aiming for Oil

A \$2 million grant has come to M.I.T. from Standard Oil Co. of Ohio for a study of problems—and their solutions—in recovering Arctic oil and gas.

Managing sea ice and difficult foundation conditions while protecting the fragile environment are among the critical issues, says Professor Charles C. Ladd of the Department of Civil Engineering, which will share the funds with the Department of Ocean Engineering. There will be several research projects, including support for graduate students, during the five-year life of the grant, and a series of seminars and symposia.

Sohio's grant to M.I.T. was one of five resulting from a \$10 million "centers for scientific excellence" competition. Other winners: the University of Cincinnati (membrane technology), the University of Illinois (crop molecular genetics), Pennsylvania State University (mining technology), and Stanford University (forecasting reservoir performance). □

## To Keep Them Working, Keep Them Moving

Most people go through three phases as they mature in their jobs, says Professor Ralph Katz of the M.I.T. Sloan School of Management; he calls the stages socialization, innovation, and stabilization. And as their members mature in their work together, research and development groups go through the same three stages.

The first stage is characterized by the uncertainty of inexperience. Then comes the adventurous spirit that flowers with confidence. And finally there is the sense of comfortable self-satisfaction based on mature experience.

For the first months on a job, most of us spend most of our energy coming to terms with our new environments, figuring out what to do and how to behave—the time of socialization. As this process unfolds, we gain confidence in our work and its settings and soon come to the time of innovation, when most of our attention can be given to a task that is still fresh and challenging. Then comes a gradual transition to stabilization, when the job becomes "old hat"—less exciting and more habitual. That's not a time of dissatisfaction or poor performance, says Professor Katz; such workers are typically very good at their jobs and "very satisfied with the comfortableness and predictability of their work environments." But it's a time of loyalty to precedent, reduced vigilance, and less willingness to innovate.

The timing of these transitions in people depends on many factors—the nature of the job, the nature of their experience and training, the kind of supervision and responsibility. In research and development groups, the change from uncertainty to achievement seems to come when average



ILLUSTRATION: JON McINTOSH

tenures in the group reach about 1.5 years, and the next transition—to self-satisfied maturity—comes about three to four years later.

The important part of all this for research and development managers is that project performance correlates tidily with group longevity—the average tenures of all project members, says Professor Katz. His research shows that the most productive research and development groups are those with group longevity between 1.5 and 5 years.

Groups' communication patterns are symptomatic of the changes that come with increasing longevity. Project teams with group longevity of five or more years have less contact than younger groups among themselves, with other groups in the same organization, and with outside professional colleagues. And unfortunately, communication deteriorates especially in the forms of communication most critical to high performance—contacts with outside professionals in the case of research groups and within the organization in development groups.

To research and development managers Professor Katz has some simple advice: keep track of group longevity, and keep people moving. To some extent, of course, that's just common sense. New members bring to a group fresh ideas and approaches—and a fresh eye for looking at old problems. But there's more to it than that, Katz thinks. "Periodic additions or rotations can help *prevent* the onset of the stabilization processes associated with high longevity," he says.

One word of warning: When a "stabilized" researcher moves into a new group, that worker's progress through socialization and innovation has to be repeated—with a period of reduced productivity. No gain comes without its price. □

## Summer Session

More than 80 short courses, ranging from one to four weeks in length, are planned at M.I.T. for the 1984 Summer Session. The subjects cover most of the academic areas represented at M.I.T.—chemical processes, economics, computer science, microscopy, materials, machines, nuclear power, toxicology, transportation, management, linguistics, nutrition . . .

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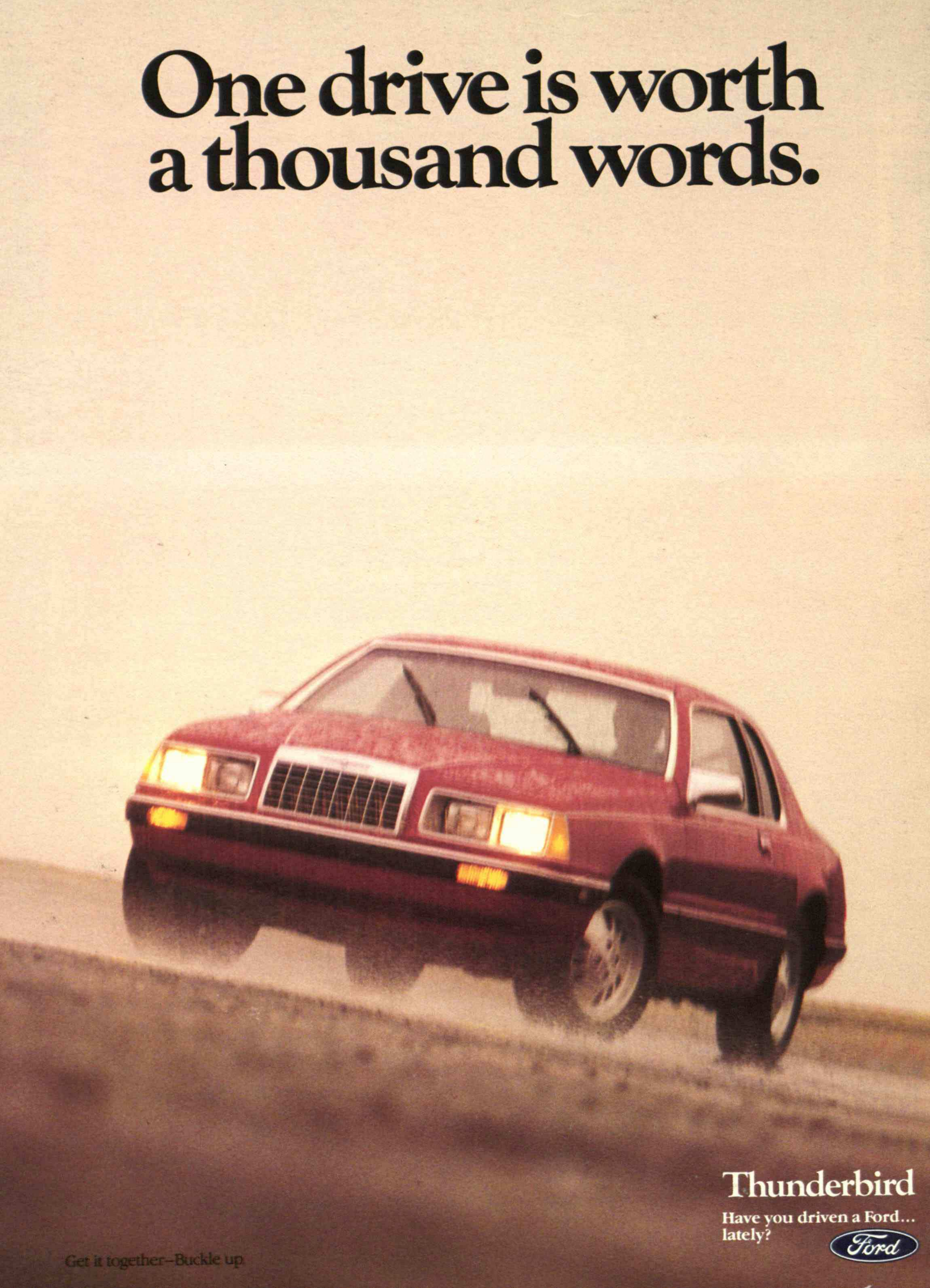
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